The Institution of Gas Engineers

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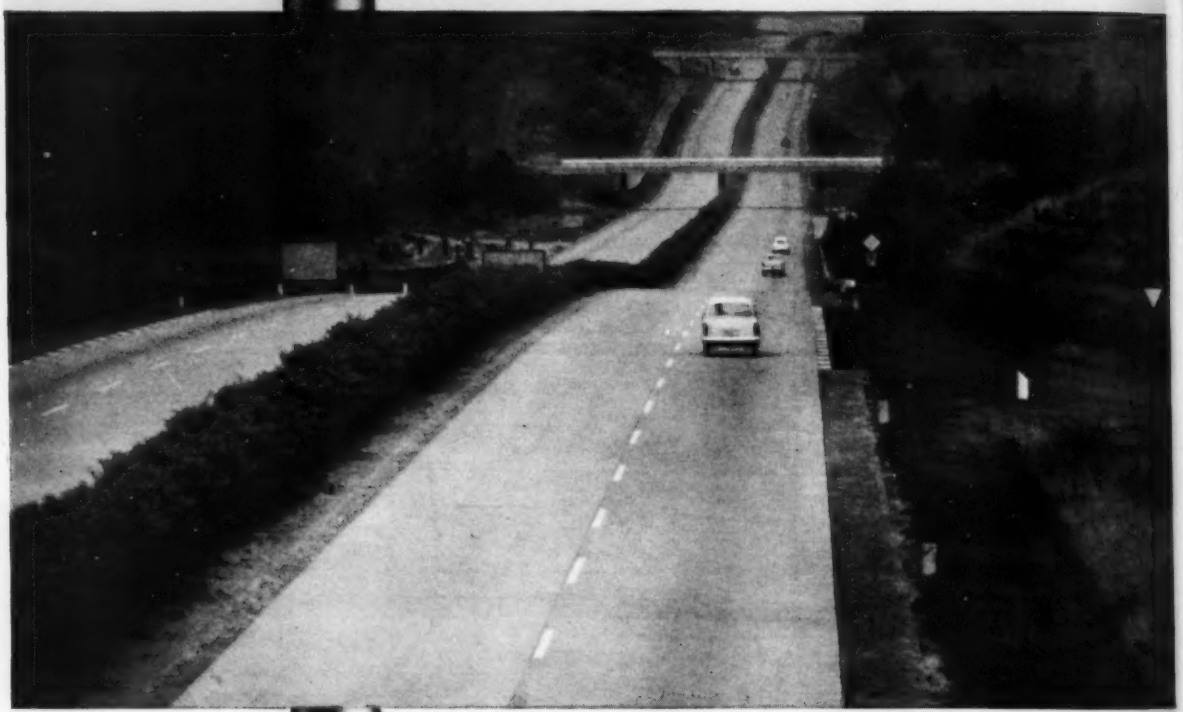
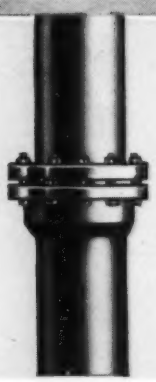
A SAFE JOURNEY FOR GAS TO HØRSHOLM





The above shows the motor-road which leads from Copenhagen almost to Elsinore. Along 8 miles of this road Stanton pipes have been laid for the supply of gas from the Strandvejas Gasvaerket to the town Hørsholm.

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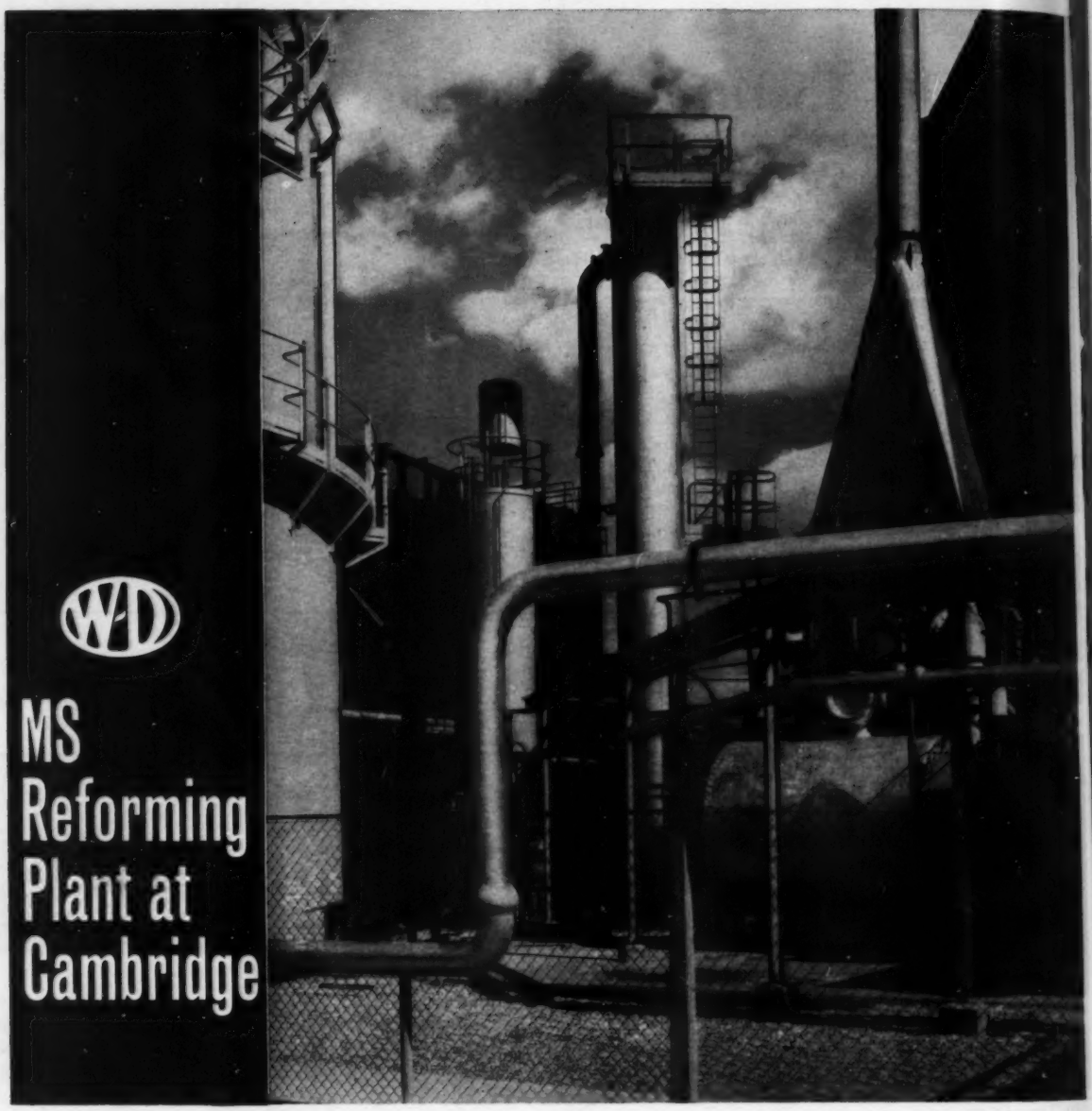

The W-D/MS Reforming Plant recently put into operation at the Cambridge Works of the Eastern Gas Board is the first installation of its kind to be completed in this country. It will provide over 2 million cubic feet of town gas daily. The Plant, which employs a cyclic catalytic process, is designed to use light petroleum distillate as feedstock and comprises two MS 32 reforming units each controlled by an automatic operator.

Two larger capacity plants are under construction for the Eastern Gas Board at Norwich and for the North Western Gas Board at Crewe.

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GAS PRODUCTION AT ROMFORD WORKS

By D. R. Coote, B.Sc.(Chem.), A.M.I.Gas E., A.M.Inst.F.
Senior Assistant Engineer, Beckton Works, North Thames Gas Board

Communication No. 594

Submitted by The British Junior Gas Associations' Joint Council

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I SUMMARY

The paper by Burns and Stewart*, presented in May, 1959, described the conception and design of the refinery gas reforming plant at the Romford Works of the North Thames Gas Board, and presented valuable information on the composition and properties of refinery gases, together with the techniques involved in their utilization. Gas-making results and efficiencies were also discussed and analysed very fully. Since that time, a further two years have elapsed, years that have seen a second oil refinery adding its quota of refinery gas, the *Methane Pioneer* project supplying another raw material, and the provision for the use of primary flash distillate and liquefied petroleum gas on the same plant.

The present paper draws on this rich fund of operational experience and shows how outputs and efficiencies have risen to levels even higher than reported by Burns and Stewart. The gas industry, however, is seeking to produce gas cheaply as well as efficiently, and sections of the paper are devoted to a critical examination of the principles that must be followed to achieve both of these objects on the Romford plant. The results of many plant tests are presented and discussed, and it is shown how these have influenced operational methods and enabled various problems to be overcome.

Gas is manufactured also in carburetted water gas and catalytic oil gas plants, both very small in comparison with the reforming plant. These units are described, together with their operational features and results. It has thus been possible to present an overall picture of gas manufacture at Romford after a transformation that has been such a memorable landmark in the history of the North Thames Gas Board.

II INTRODUCTION

(A) GAS-MAKING PLANT

The recent installation at Romford of large new gas-making plants designed for operation on oil refinery feedstocks has completely changed many of the aspects of gas production on this works. In April, 1959, when an old continuous vertical retort house was finally closed down and scheduled for demolition, Romford became the first gas works in the North Thames Gas Board, and the largest in the country, to discontinue the coal carbonizing process completely. The capacity of the works was raised from 5 mill. cu. ft/day in 1957 to 50 mill. cu. ft/day in 1959, and over the same period of time there has been a remarkable change in the costs of gas manufacture. Whereas, in 1957, Romford was one of the most expensive manufacturing stations in the Board, by 1959 it had become the cheapest. It is equally notable that, by virtue of the type and design of the plants now in operation, this considerable enlargement of the station capacity has been achieved without any increase in the total number of personnel employed.

Gas is produced in a carburetted water gas plant, a catalytic oil gas plant and the refinery gas reforming plant, all of which were installed by Humphreys & Glasgow, Limited, and which commenced gas making in December, 1950; February, 1958, and May, 1958, respectively. Table 1 sets out certain information that makes it possible to view these plants in the proper perspective, and Table 2 shows the allocation of total manpower on the works.

TABLE 1.—*The Three Gas-making Plants.*

Plant	Number of Units	Operators and Attendants per Shift	Maximum Daily Output (Mill. cu. ft)	Available Feedstocks	Approximate Daily Consumption of Feedstock (Tons)
1	2	3	4	5	6
C.W.G. Plant	1	2	3·0	Furnace Coke Gas Oil P.F.D.	35 2 20
C.O.G. Plant	2	2	6·0	Medium Fuel Oil P.F.D. Refinery Gas	18 69 —
Reforming Plant	4	5	45·0	Refinery Gas P.F.D. L.P.G.	475 — —
TOTAL	7	9	54·0	—	619

TABLE 2.—*Total Personnel on Works.*

Duties	Total Numbers	
	Day Work	Shift Work
1	2	3
Supervisory Staff (Engineering Staff and Foremen)	9	8
Laboratory Staff	6	—
Gasmaking Plants (Operators and Attendants)	—	36
Other Processes (Steam-raising, purification, gas pumping and drying, *etc*)	—	20
Maintenance Workers	60	—
Yard Workers	30	—
Total	105	64

It can be seen from Table 1 that, for the same load factor, because of the difference in the numbers and sizes of the units involved, the labour charges per therm of gas produced from the carburetted water gas, catalytic oil gas and reforming plants respectively, are in the ratio 6 : 3 : 1. This is one of the reasons why the carburetted water gas plant has recently been reserved for peak-load operation only, while the catalytic oil gas plant occupies an intermediate position between base-load and peak-load plant. The reforming plant is, of course, a base-load plant.

It is not surprising to find, in Table 2, that the total number of maintenance workers, which includes skilled tradesmen and their mates, exceeds the total number of process shiftworkers.

(B) OTHER PLANT

Various other sections of plant are itemized under the following headings:—

Boiler-house

Four Lancashire boilers, three fired on medium fuel oil and one on breeze. Each is rated at 8,000 to 10,000 lb/hr, and steam is supplied to the catalytic oil gas plant and for various other services, including gasholder anti-freezing.

Water-softening Plant

A fully automatic plant, softening a mixture of well water and town water. Having a capacity of 200,000 gal/day, it operates on the principle of restricted hydrogen ion ex-

* The Romford Gas Reforming Plant. Burns, J., and Stewart, E. R. *Inst. Gas Eng. Comm.* 550.

change followed by sodium ion exchange, employing sulphuric acid and brine as regenerative materials.

Odorizing Plant

A small unit continuously injecting tetrahydrothiophen odorant to the reformed gas at inlet holders at the rate of 1 lb/mill. ft³.

Gasholders

The original holder capacity of 4·5 mill. ft³ (in three holders) has been augmented to 10·5 mill. ft³ by the installation of two four-lift spirally-guided holders, each of 3·0 mill. ft³ capacity.

High-pressure Pumping Plant

Four identical twin-cylinder reciprocating compressors, each rated at 12·0 mill. ft³/day, provide a total pumping capacity of 48·0 mill ft³/day into the Board's grid system at pressures up to 25 lb in² gauge. Two machines are driven by 880 h.p. electric motors running on the 11 kV supply, and two by National Gas Engines operating on diesel oil.

High-pressure Gas Drying Plant

A Calcium chloride gas drying plant, designed for operation with gas pressures of 25 lb in² gauge and situated at the outlet of the high-pressure gas pumps.

Low-pressure Gas Drying Plant

A much smaller plant dealing with the local district consumption of 3·0 to 6·0 mill ft³/day, which is supplied through a station governor.

Primary Flash Distillate Storage

The complete installation, designed in accordance with the I.G.E. Safety Recommendations M9, includes a bunded 100,000 gal. storage tank, pressurized at the top to 16 in w.g. gas pressure from one of the gasholders. An atmospheric breather valve gives additional protection against excessively high or low pressures above the primary flash distillate level. The tanker-unloading bay, which is also bunded, is enclosed with chain-link fencing, together with the unloading pumps and the delivery pumps, which supply primary flash distillate from the tank to the three gas-making plants at pressures of 80 to 100 lb in² gauge. Full provision is made for the draining and purging back of primary flash distillate lines, and remote stop-buttons situated at strategic points in the control-rooms and the plant areas enable the delivery pumps to be shut down instantly in the event of any emergency. An adjacently housed mobile fire-pump, normally connected to the top of the storage tank, can deliver copious quantities of fire-extinguishing foam into the tank within 1 min of fire being detected.

III THE CARBURETTED WATER GAS PLANT

(A) Plant Design

This plant, which was placed on order prior to Vesting Day, was part of the new development scheme planned by the Romford Gas Company. One unit, with a nominal rating of 2·5 mill. ft³/day, was installed, provision being made for the later addition of a second unit if it were required. By modern standards, this size of plant is very small indeed, but the capacity was governed by what was then the level of gas demand on the relatively small district of the Company.

Having a water-sealed self-clinkering generator of 7 ft diameter, with the usual carburettor, superheater, waste-heat boiler and conical-based washbox, the plant is automatically operated by Lockheed hydraulic equipment. All the modern features of design, which are now commonly accepted, were incorporated in the plant, together with one item that was somewhat of a novelty at the time. This was a water-sealed back-run valve of the butterfly type, which is illustrated in Figure 1. Instead of a parallel-slide valve situated near the connexion to the generator base, this butterfly valve was placed at the far end of the back-run main, immediately above the washbox. Water is supplied continuously from the circulating system, either flushing down into the washbox when the valve is open, or sealing it when shut and overflowing into a seal-pot. This departure from the traditional back-run valve thus avoided the problems associated with pitchy carbonaceous deposits and the corrosive operating conditions that make the parallel-slide valve so vulnerable. It is interesting to note that this was the forerunner of similar valves that are now installed on catalytic oil gas plants.

(B) Plant Operation

Operation of this plant when using gas oil as an enriching feedstock has given very good results, but the high specific gravity of carburetted water gas, together with the rising prices of gas oil, added impetus to the search for alternative feedstocks. The increasing availability of P.F.D. at an attractive price, and the encouraging experiences with this material on other plants, suggested that P.F.D. was the best alternative to proceed with at this time. It was anticipated that up-run enrichment and back-run reforming would yield higher plant outputs, gas with a lower specific gravity, and a cheaper therm. The intention

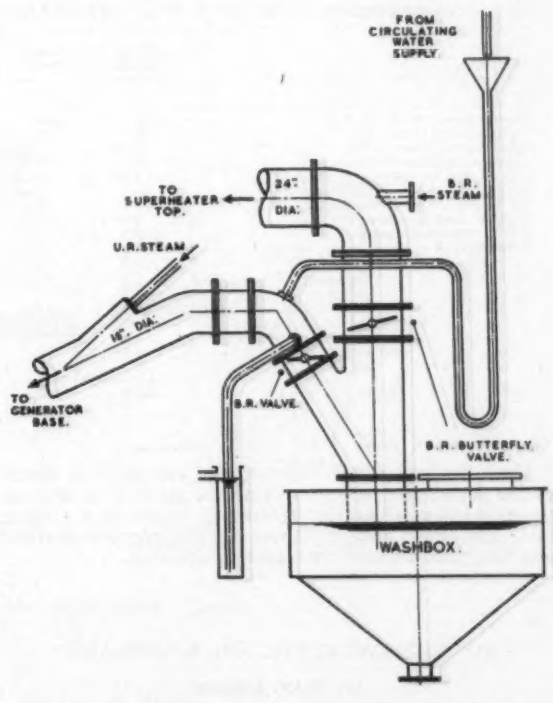

FIGURE 1.—*Carburetted Water Gas Plant: Water-sealed Back-run Valve.*

was to change from gas oil usage to P.F.D. usage in three stages:—

Stage 1.—Replacement of enriching gas oil by P.F.D.

Stage 2.—Injection of P.F.D. at the carburettor top during the back-run.

Stage 3.—Injection of P.F.D. at the superheater top during the back-run.

Stage 1

This occupied a few days only, and merely provided the opportunity for checking the operation of the new P.F.D. equipment and instituting what seemed necessary in the way of safety routines. The new cracking temperatures were established before operating conditions became complicated by back-run reforming of P.F.D.

Stage 2

When injecting P.F.D. into the carburettor during the back-run, the general lowering of temperatures at the top of this vessel soon caused difficulties with the ignition of the the blow-gases. This was not unexpected, and higher air: steam ratios enabled satisfactory ignition to be restored. During the back-run period, an instantaneous ratio of 1·4 lb of steam per lb of P.F.D. was maintained, while during the up-run period 1 gal of gas oil per cycle was injected through the centre of the P.F.D. spray. After two months' operation in this fashion, during which the plant ran very smoothly indeed, there was still no indication of any deposit or blockage either in grate rings, or in the back-run main, washbox, or condenser, The plant was easy to control, and tar production was negligible. Table 3 gives comparative data for operation with normal gas oil enrichment, with P.F.D. admission at the carburettor for up-run enrichment and back-run reforming.

TABLE 3.—*Comparative Data for C.W.G. Manufacture.*

	Using Gas Oil	Using P.F.D.
1	2	3
Make per set day (thous. ft³)	2,850	3,084
Calorific value (B.t.u./ft³)	506	495
Specific gravity (air = 1·00)	0·67	0·61
Coke consumption (lb/thous. ft³)	33·9	25·1
Gas oil used on up-run (gal./thous. ft³)	2·00	0·20
P.F.D. used on up-run (gal/thous. ft³)	—	1·44
P.F.D. used on back-run (gal/thous. ft³)	—	0·81
Total oil used (gal/thous. ft³)	2·00	2·45
B.W.G. therms/ton coke	153·4	155
Therms/gal oil	1·37	1·31
Gas analysis :—CO_2	3·6	3·5
O_2	0·5	0·8
C_nH_m	7·9	7·9
H_2	36·7	41·8
CO	32·9	25·6
CH_4	7·8	7·6
C_2H_6	2·1	2·7
N_2	8·5	10·1
	100·0	100·0

Stage 3

Until the back-run P.F.D. point of admission is moved to the superheater top, it will not be possible to increase the proportion of back-run reforming, reduce the air: steam ratio, and obtain greater outputs and lower specific gravities and coke consumption than already achieved.

IV THE CATALYTIC OIL GAS PLANT

(A) PLANT DESIGN

The first stage of the North Thames Gas Board's plan to dispense entirely with coal carbonization at Romford commenced with the installation of this plant. There had previously been only very limited experience with this type of plant in the gas industry, and the Board felt very strongly that, although great success had attended the design and operation of water gas generators of ever-increasing diameter, it could not yet be claimed with any degree of confidence that all the problems of correct distributional flow through the active catalyst beds in the vessels of these new plants had been completely overcome. With this in mind, therefore, a plant was ordered having two identical units, each with a rated capacity of 2·0 mill. ft³/day when using medium fuel oil as a burner and process feedstock. The plant was to be equipped for utilizing refinery gas as an alternative process feedstock, and later modifications gave the added facilities for employing P.F.D. Whereas the refinery gas reforming plant was to be of the non-regenerative or self-steaming type, the catalytic oil gasification plant was of the regenerative type. In order that the features of both designs may readily be compared, they are illustrated in simple diagram form in Figures 2 and 3.

The make gases pass from the washboxes to a scrubber-cooler, a static brush-packed naphthalene washer through which creosote is circulated, through a 50,000 ft³ relief holder to two electrically-driven turbo-exhausters fitted with scoop-controlled fluid-flywheel couplings. After passing through an electrostatic detarrer, the gas enters the oxide purifiers.

Steam is supplied to the plant at a pressure of 125 lb/in² gauge and the pass-out from the air-blower turbines supplies process requirements through a steam accumulator, together with makeup steam from a reducing valve. Steam is also supplied for heating the medium fuel oil (in a thermostatically controlled tubular heater) and the tar decantation tanks.

The liquor circulating system includes tar and liquor separators, water-cooling tower, and hot and cold water circulating pumps.

The catalyst in the catalytic oil gasification plant is of the YN " Onia-Gegi " type, in the form of rough pebbles of approximately ¼ in diameter, and there is a total of 12 to 13 tons of catalyst in each reactor. The magnesia support, which is impregnated with nickel, tends to counteract the undesirable effects of ash and sulphur attack, and this form of catalyst is, therefore, suited to dealing with medium fuel oil, gas oil, or P.F.D.

(B) GASIFICATION OF MEDIUM FUEL OIL

The plant was designed for operation on a medium fuel oil with the following characteristics:—

Viscosity	800 to 1,000 s. Redwood No. 1 at 100°F.
Conradson Carbon	Below 10·5 per cent.
Sulphur	Below 4·0 per cent.
Asphaltenes	Below 3·0 per cent.
Ash	Below 0·05 per cent.
C/H Ratio	Below 7·6 per cent.
Specific gravity at 60°F	0·95 to 0·97.

Early operation with medium fuel oil was hampered by constantly recurring difficulties associated with the hydraulic system. The original arrangement was such that not only were unsafe valve movements prevented by the mechanical interlocks in the automatic operator, but, in addition, undue slowness of any valve movement, or the incomplete travel of any valve, would instantly shut the set down. Many of the valve movements were initiated in sequence fashion, the completion of the first valve movement sending a hydraulic impulse to actuate a second valve, and so on. This called for an accuracy of adjustment that it was

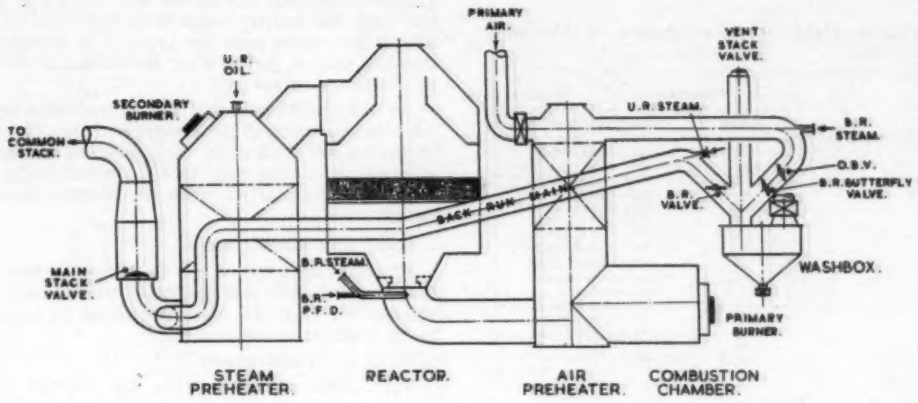

FIGURE 2.—*Catalytic Oil Gas Plant: Regenerative System.*

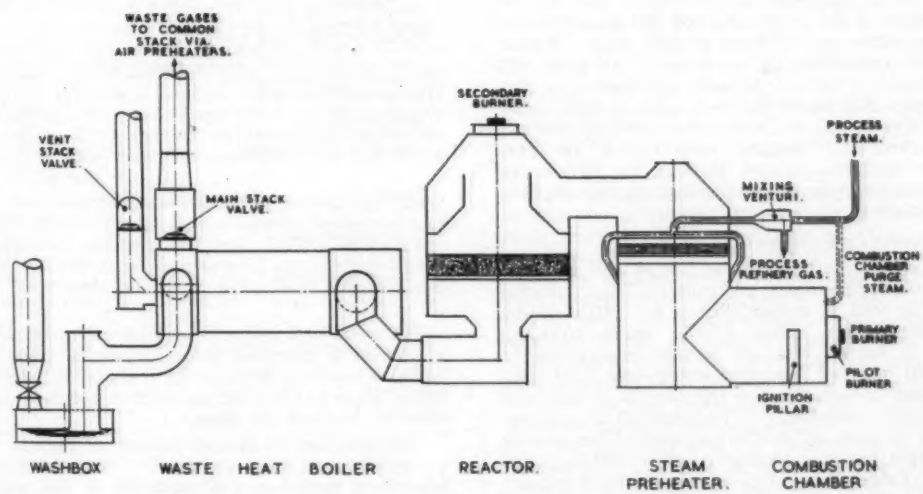

FIGURE 3.—*Reforming Plant: Non-regenerative System.*

just impossible to maintain, and smooth operation was not achieved until the very complex hydraulic system was simplified. What was then considered a satisfactory working cycle was then established, and is given in Table 4.

TABLE 4.—*Operating Cycle for Gasification of Medium Fuel Oil.*

	Percentage		Duration (100 per cent = 470 s)
	Open	Shut	
1	2	3	4
Primary burner	3	28	117
Secondary burner	—	—	—
Primary air	2	50	226
Main stack valve	0	50	235
Vent stack valve	0·5	54	251
Process oil	52	94	197
Process steam	50	99·5	233
Back-run	—	—	—
Top steam purge	0	2	9
Base steam purge 1	50	52	9
2	94	99·5	26

When gasifying medium fuel oil, there is no need to employ the back-run process, for the combustion of the carbon deposited on the steam preheater chequers and on the catalyst serves to restore some of the heat required at these points. The back-run main carries, therefore, only the low-pressure process steam and the high-pressure base purge steam. All of the process oil is sprayed into the vaporizing chamber above the chequers of the steam preheater. It was soon discovered that the successful operation of the plant depended on the following factors:—

Control of Carbon

The deposition of carbon *per se* is not an embarrassment provided that it is completely combusted by the end of each heating phase; if this is not achieved, the accumulation of carbon can prove very difficult to deal with. Proper attention to the combustion air and primary air rates will secure full control of carbon deposits, although it is also essential to ensure that the oil injection spray is maintained clean and delivers the oil uniformly over the cross-section of the steam preheater. Regular inspection of the preheater chequers and the catalyst, through the sight-cocks provided, is vital in order to ensure that carbon deposits are not accumulating.

Control of Catalyst Performance

The combustion of carbon on the calayst can give rise to very high local temperatures, particularly if distributional flow through the bed is uneven during any phase of the cycle. At temperatures above 950°C, under oxidizing conditions, it is known that the metallic nickel can be oxidized to NiO and can then pass slowly into solid solution in the magnesia support, and the catalyst activity will therefore gradually diminish. Unfortunately, it is sometimes necessary to approach this temperature if the calorific value of the make gas is to be kept down to 500 B.t.u./ft³. At the higher temperatures, the nickel activity increases, there is a greater tendency for thermal decomposition of the oil, more carbon is deposited, and the temperature continues to rise. Ultimately, the catalyst will fuse, and its activity will be irretrievably lost. Considerable vigilance is therefore necessary to ensure that this vicious spiral of rising temperatures is not encountered.

If the catalyst is maintained under strongly oxidizing conditions for periods of some hours (e.g., when intermittent heat-raising is carried out in order to have the plant in a continual state of readiness for gas making), even at temperatures as low as 700° to 800°C there is a loss of nickel into the magnesia in the form of NiO. However, when gas making is commenced, the cyclic reducing phases will progressively recover the nickel into its active state; after a few days, the activity seems to be fully restored. Nevertheless, it has never been the practice at Romford to keep a standby unit at gas-making temperatures for longer than is absolutely necessary.

As it is also known that partial hydration of the catalyst pebbles can occur in the presence of steam at temperatures of up to 300°C, leading to a physical breakdown of the material, it is important that no steam should be allowed to contact the catalyst when the plant is standing at these temperatures.

Control of Calorific Value

A steam : oil ratio of 1·0 to 1·1 lb/lb was found to be suitable, and this was normally maintained, the calorific value of the make gas being controlled by minor alterations to the catalyst temperatures.

Control of Temperatures

Very little adjustment to the burner oil rate was necessary, but regular cleaning of the burner nozzle could not be neglected. As the operators gained experience, it was found possible to discontinue the use of the secondary burner without losing flexibility of control.

Table 5 gives the normal operating details, and Table 6 the operating results for the month of October, 1958.

TABLE 5.—*Operating Details when Gasifying Medium Fuel Oil.*

	Quantities per Cycle	Quantities per Minute
1	2	3
Burner oil (gal at 60°F)	3·5	1·8
Combustion air (ft³)	10,300	5,300
Primary air (with burner open) (ft³)	10,500	5,400
(with burner shut) (ft³)	15,400	9,000
Excess air available for carbon combustion (ft³)	30,080	—
Excess air/gal process oil (ft³)	735	—
Process oil (gal at 60°F)	41	12·5
(lb)	408	124·3
Process steam (lb)	505	130
Top purge h.p. steam (lb)	15	95
Base purge h.p. steam (lb)	100	170
Temperatures :	°C	
Oil at meter	100	
Combustion chamber	800 to 900	
Air preheater top	200 to 300	
Catalyst base	850 to 900	
Catalyst top	750 to 850	
Steam preheater top	700 to 800	

No waste-heat boiler is incorporated with the plant, and all steam is imported from the works boiler-house. No account has been taken of the fuel consumed in raising this steam when calculating the therms obtained per gallon of total oil used on the plant.

The high carbon dioxide content of the gas was not due to insufficient cyclic purging, but arose as a result of the successive oxidation and reduction of the nickel catalyst. After oxidation during the heating phase, the reduction at the beginning of the gas-making phase produces a large quantity of carbon dioxide. This cannot be eliminated to atmosphere without incurring an objectionable stack discharge.

The tar produced in the plant can easily be separated with the assistance of a surface activating agent, and the quantity is sufficient to satisfy the burner requirements. The water content of the tar is normally about 1 per cent.

TABLE 6.—*Operating Results for October, 1958.*

1	2
Total output (thou. ft³)	75,249
Calorific value (B.t.u./ft³)	498
Therms	375,105
Total set days worked	37·12
Average make per set day (thou. ft³)	2,027
Oil used at burner (gal at 60°F)	24,235
Oil used for process (gal at 60°F)	278,853
Burner oil used/thou. ft³ (gal)	0·32
Process oil used/thou. ft³ (gal)	3·71
Therms/gal total oil	1·24
Therms/gal process oil	1·35
Steam usage in sets/thou ft³ (lb)	57·0
Steam usage on ancillaries/thou. ft³ (lb)	33·0
Gas Analysis :—	
CO_2	12·5
O_2	0·6
C_nH_m	6·1
H_2	46·2
CO	15·4
CH_4	11·7
C_2H_4	2·0
N_2	5·5
	100·0
Specific gravity	0·61

Back-pressure difficulties arising in the steam preheater as a result of disintegration of the top few courses of chequer bricks were eliminated only after repacking these bricks in a more open formation, and placing at the top a set of hollow cast iron domed blocks.

(c) GASIFICATION OF PRIMARY FLASH DISTILLATE

During the Spring of 1959, preparations were made for the gasification of P.F.D., and for the first time it was necessary to employ the back-run cycle. The injection of the back-run P.F.D. (together with the back-run steam) at the air preheater top, was intended to exploit fully the available regenerative capacity of the air preheater. The up-run steam and P.F.D. were injected at the same points as were used for up-run medium fuel oil gasification.

A few days of operation without employing the back-run confirmed that, with the considerably lower carbon deposition, temperatures could not be satisfactorily controlled to yield a gas with a calorific value of 500 B.t.u./ft³ without producing a very unmanageable tar in the washbox and the scrubber. Even the use of the secondary burner did not enable a satisfactory temperature distribution to be obtained in the set.

The cycle was shortened to 350 s (to reduce cyclic temperature fluctuations), the back-run was incorporated and the purging periods suitably adjusted. Table 7 shows the operating cycle, Table 8 the operational details, and Table 9 the results for November, 1959, when only one unit was at work.

TABLE 7.—*Operating Cycle for P.F.D. Gasification.*

	Percentage		Duration (100 per cent = 350 s)
	Open	Shut	
1	2	3	4
Primary burner	2	39	129
Secondary burner	—	—	—
Primary air	1·5	39	131
Main stack valve	0	44·5	156
Vent stack valve	1	47	161
Up-run P.F.D.	72·5	94	75
Up-run steam	71	0	102
Back-run P.F.D. and steam	44	71	95
Top steam purge : 1	0	1·5	5
2	39	44·5	19
Base steam purge : 1	71	72·5	5
2	94	0	21

TABLE 8.—*Operating Details when Gasifying P.F.D.*

1	Quantities per Cycle	Quantities per Minute
	2	3
Burner oil (m.f.o.) (gal at 60°F)	5·0	2·33
Combustion air (ft³)	11,200	5,200
Primary air (ft³)	5,450	2,500
Back-run P.F.D. (gal)	22·0	13·9
(lb)	154	97
Up-run P.F.D. (gal)	18·0	14·4
(lb)	126	101
Percentage back-run P.F.D.	55%	—
Back-run steam (lb)	182	115
Up-run steam (lb)	204	120
Top purge h.p. steam (lb)	38	95
Base purge h.p. steam (lb)	74	170
	°C	
Temperatures :		
M.f.o. at meter	100	
Combustion chamber	850 to 900	
Air preheater top	180 to 200	
Catalyst base	930 to 950	
Catalyst top	840 to 860	
Steam preheater top	650 to 700	

TABLE 9.—*Operating Results for November, 1959.*

1	2
Total output (thou. ft³)	77,715
Calorific value(B.t.u./ft³)	506
Therms	393,281
Total set days worked	29·84
Average make per set day (thou. ft³)	2,604
M.F.O. used at burner (gal 60°F)	36,586
P.F.D. used for process (gal)	294,494
Burner M.F.O. used per thou. ft³ (gal)	0·47
Process P.F.D. used per thou. ft³ (gal)	3·79
Therms per gal of total oil	1·19
Therms per gal of process P.F.D.	1·34
Steam usage in sets per thou. ft³ (lb)	47·2
Gas Analysis :—	
CO_2	7·7
O_2	0·7
C_nH_m	5·5
H_2	48·3
CO	19·0
CH_4	11·2
C_2H_4	2·8
N_2	4·8
	100·0
Specific gravity	0·56

Early operation had yielded outputs of 3·0 mill. ft³ per set day with a calorific value of 550 B.t.u./ft³. Reduction of the steam : P.F.D. ratio from 1·2 lb/lb to 1·0 lb/lb did not materially reduce this calorific value, and it became necessary to work with a lower plant output and catalyst base temperatures nearer to 950°C. Quantities of carbon and tar were produced, which caused obstructions in the scrubber-cooler. It became apparent that the preheating of the back-run P.F.D. in the air preheater and the high temperatures (850° to 900°C) in the connecting main between the air preheater and the reactor base caused excessive thermal cracking and carbon formation. Temperature distribution in the catalyst bed suffered, and hot patches were observed at the top of the catalyst. Alterations to the up-run and back-run P.F.D. proportions were of no avail, and it became necessary to discontinue gas making. The hotter portions of the catalyst were found to have fused into a solid mass, and much of this material had to be replaced.

During the Summer and Autumn of 1960, various modifications of the operational techniques and of the plant were carried out, including the "throating" of the inlet main at the reactor base, and an alternative injection point for the back-run P.F.D. and steam just below this throat,

as shown in Figure 2. In order that the Winter of 1960-61 might be faced with more confidence, however, a return was made to the gasification of medium fuel oil. Nearly 500 mill. ft³ of gas had been produced by the gasification of P.F.D., and the lower specific gravity of this gas is sufficient inducement to warrant further experimentation during the forthcoming Summer months.

V EARLY EXPERIENCES ON THE REFORMING PLANT

(A) Operational Results

The earlier paper by Burns and Stewart has described very fully the plant design and cyclic operation. The plant diagram in Figure 3 will assist the understanding of further details, which are given in subsequent sections.

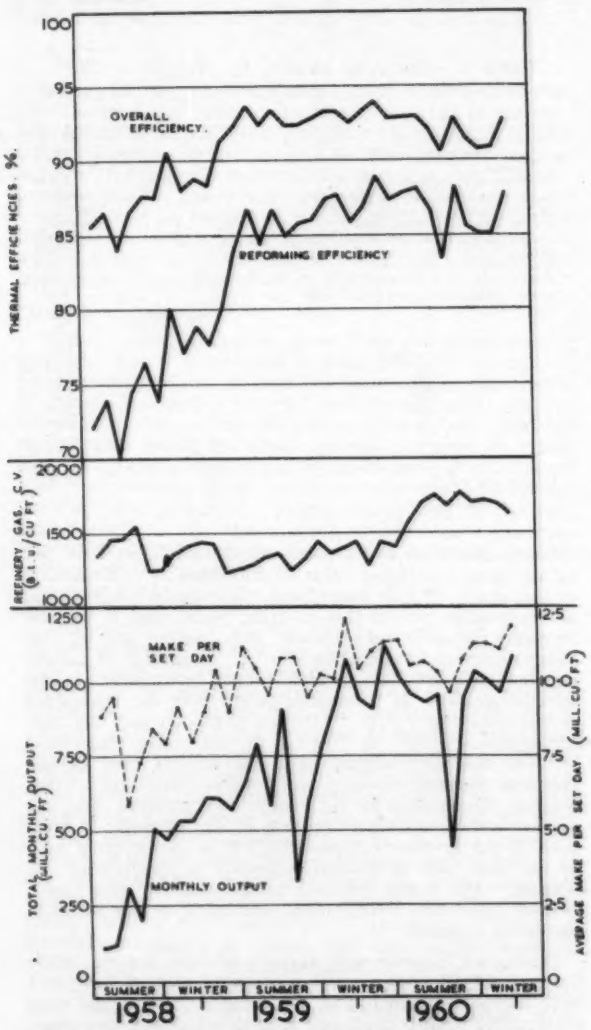

FIGURE 4.—*Reforming Plant: Early Working Results.*

The results obtained during the first 33 months of plant operation (presented in Figure 4) express graphically, much better than words can describe, what a satisfactory performance the plant has given. Although the units were originally rated at 9·0 mill. ft³/day each, a maximum of 14·0 mill. ft³/day has been realized, and an average of above 12·0 mill. ft³/day has been maintained over the course of a month's operation. Under the terms of the original agreements with the oil refineries, the maximum contracted quantity of gas to be supplied would yield no more than 720 mill. ft³/month output at Romford; but, as a result of the greatly increased quantities of gas that have been offered and accepted, it has been possible to produce over 1,100 mill. ft³/month, and yet still leave some refinery gas available for use at Beckton gas Works, to which the original refinery gas main has now been extended. The greatest daily output that has been achieved so far was 43·6 mill. ft³, when all four units were working together, well below their maximum rates. It is noteworthy that, although the normal daily output (with three units in operation) is about 35 mill. ft³, the plant is now scheduled for an available capacity of 45·0 mill. ft³.

With refinery gas calorific values of 1,300 to 1,400 B.t.u./ft³, the overall efficiency of the plant had risen to a level of 94·0 per cent by March, 1960. When the refinery gas calorific value rose to 1,700 to 1,800 B.t.u./ft³, however, reforming and overall efficiencies fell to lower levels. This was not unexpected, and when the refinery gas calorific value fell again, in January, 1961, there was an immediate rise in the plant efficiencies. It should be stressed that throughout the whole of the period under review the catalyst in use in the units was still the original material that had been charged into the plant in April, 1958. By the end of January, 1961, some of this catalyst had already endured a working life of over 16,000 hr, representing 200,000 cyclic changes from oxidizing to reducing conditions.

(B) Plant Reliability

Plant reliability has been of a very high order. In the five-month period 1st November, 1959, to 1st April, 1960, for instance, out of a total of 152 days, one of the units operated for 150 days. This period of smooth operation was then brought to a halt by a planned maintenance shutdown for which this unit was scheduled. This is a very satisfactory performance for a cyclically operating unit.

Figure 5 shows the frequency distribution of daily plant outputs for the year 1960, discounting the 15 days of complete shutdown scheduled in August for maintenance purposes. There were only two days during the Summer period and four during the Winter period when the refinery gas deliveries were below the declared minimum quantities, and more than 98 per cent of the daily plant outputs were, therefore, in excess of the expected minimum quantities. The skew nature of the distribution arises from the fact that outputs of less than 33 mill. ft³/day have generally been due to the lower quantities of refinery gas available, whereas outputs greater than 36 mill. ft³/day are generally possible (with three units working) only when the refinery gas calorific value is in the lower ranges. There is no doubt that, in having two sources of refinery gas (Shellhaven and Coryton), the Board can rely with more certainty upon the output from Romford.

(C) Operation with Methane

During the period March, 1959, to June, 1960, a total of over 6 mill. therms of liquefied natural gas, which had been unloaded into the Canvey Island storage tanks from the *Methane Pioneer*, were evaporated into the refinery gas pipeline and transmitted to Romford together with

the refinery gases. The methane content of the liquefied natural gas was approximately 80 to 85 per cent, and the calorific value averaged about 1,140 B.t.u./ft³. The stocks of methane proved to be a very valuable reserve and were usefully exploited on occasions when a greater output was required from Romford than the refinery gas supply alone would permit.

For six days in June, 1959, and three days in October, 1959, the plant was operating on methane only, without any refinery gas. At those times, the plant output was limited by the rate of supply of the methane, and only one unit was at work, producing 6 to 8 mill. ft³/day. No special alterations were made to operating conditions, and the reforming efficiency and overall efficiency averaged 76·9 and 88·6 per cent respectively. Although these efficiencies seemed low, a later comparison showed that they were very near to the efficiencies that would be expected when operating at such low outputs with a refinery gas feedstock. At this period of plant operation, final gas specific gravities were being allowed to rise to 0·53, while still maintaining a Wobbe Number above 680, and lean gas calorific values were normally below 300 B.t.u./ft³. Table 10 gives an interesting comparison between lean gas and final gas analyses when handling methane and when handling refinery gases in the calorific value range of 1,200 to 1,500 B.t.u./ft³.

The high inert content and specific gravity of the gases when employing the methane feedstock arose as a result of the unusually low rate of gas making and the inclusion in the lean gas of higher proportions of unpurged blow gases. Whereas the normal paraffin content of refinery gas may lie between 40 and 85 per cent, dependent on its composition and calorific value, the total paraffin content of the liquefied natural gas was about 98 per cent, and it was pleasing to find such a low proportion of paraffins in the lean gas when using methane feedstock. The proportion would no doubt have been greater at higher gas-making rates and shorter contact time with the catalyst. On the other hand, this could be offset by operating with higher catalyst temperatures.

TABLE 10.—*Comparison of Gas Analyses.*

	Methane Feedstock		Refinery Gas Feedstock	
	Lean Gas	Final Gas	Lean Gas	Final Gas
1	2	3	4	5
CO_2	10·2	7·5	9·6	7·5
O_2	0·1	0·4	0·3	0·5
C_mH_m	0·0	0·3	0·0	1·7
H_2	57·6	39·8	60·9	53·4
CO	12·5	9·3	14·4	12·1
CH_4	5·0	25·1	4·2	4·1
C_2H_4	0·3	5·1	0·1	11·1
N_2	14·3	12·5	10·5	9·6
	100·0	100·0	100·0	100·0
Specific gravity ..	0·48	0·55	0·46	0·53
Calorific value ..	280	500	291	500

(D) OPERATION WITH PRIMARY FLASH DISTILLATE

It was originally the intention that P.F.D. should be available for use on the reforming plant as a burner feedstock and as a process feedstock. As a result of the high inputs of refinery gas, however, it has not been necessary to gasify P.F.D. on the plant except for experimental purposes, although it has been used at times as a burner feedstock. For reasons of safety, it was necessary to employ the pilot burners in the combustion chamber when burning P.F.D. not merely to ensure immediate cyclic ignition at the burner, but also to ensure that in the event of any difficulty, which should cause the unit to be shut down, the consequent purging forward of the P.F.D. pipelines through the burner into the combustion chamber could be carried out with the assurance of its safe combustion.

First attempts at P.F.D. burning showed that the fine orifices of the P.F.D. burners were very vulnerable to blockage by small amounts of rust originating from the

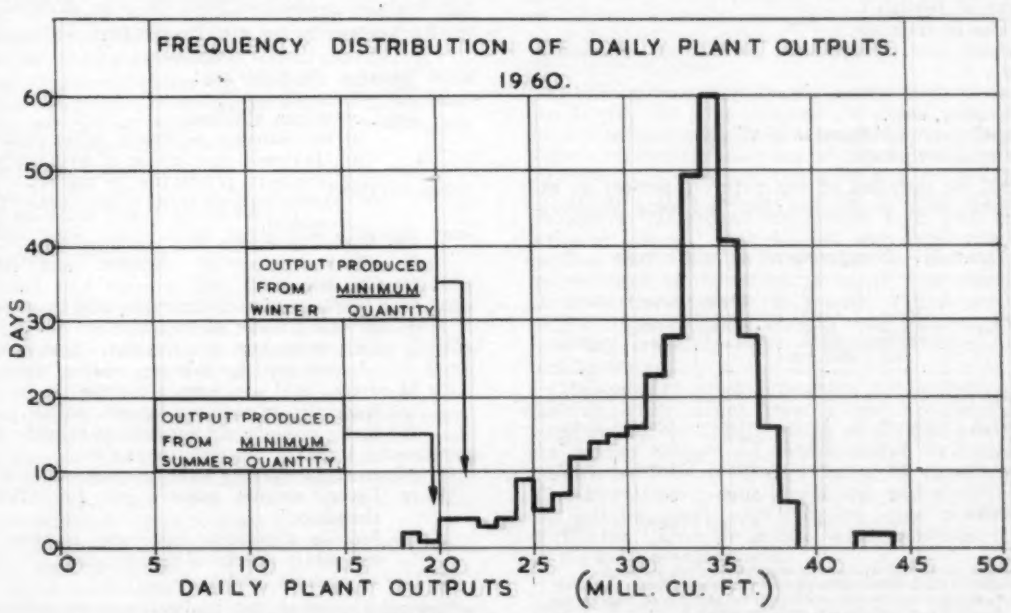

FIGURE 5.—*Frequency Distribution of Daily Plant Outputs during 1960.*

new pipework. After substituting a more effective strainer in the P.F.D. pipe before the burner, smooth and effortless burning was soon achieved, and by August, 1960, over 65,000 gall. of P.F.D. had been used on the plant. The activity of the catalyst did not appear to be affected by the use of this burner fuel, and no ill-effects were observed. The more difficult problem seemed to be the maintenance of steady pilot flame operation. The pilot burner itself protrudes through the burner air box just at the side of the primary burner. It is supplied with a regulated mixture of town gas and air from a rotary electrically driven compressor. The flame is monitored by a photo-electric cell, viewing through a sight-glass. In the event of pilot flame-failure, the photo-electric cell causes the unit to be shut down to safety; the gas/air compressor is also shut down. Although the burner operated satisfactorily, oil-mist carried forward from the compressor tended to obscure the viewing-glass, and unexpected shut-downs occurred as a result. Attention is now being given to the possibility of employing a satisfactory de-mister, an oil-less compressor, or a high-pressure gas injector.

It should, perhaps, be noted that the gas consumption of the pilot burner (approximately 5,000 ft³/day) is regarded as a burner feedstock and is added to the thermal input to the plant when calculating efficiencies of plant operation.

VI REFORMING PLANT: COST CONSIDERATIONS

(A) Cost of Gas Production

The overall cost of gas "into holder" from any plant can be divided very broadly into the following components:—

(1) Capital charges on the production plant.
(2) Capital charges on materials handling and ancillary plants.
(3) Cost of feedstock.
(4) Value of residuals.
(5) Labour costs (production, purification, exhausting, *etc.*).
(6) Process costs (steam, electricity, water, purification, odorizing, *etc.*).
(7) Repairs and maintenance of all plant.
(8) General overheads.

It is not the intention of this paper to present an exhaustive analysis of production costs, but some consideration of these factors will serve to explain the very low cost of gas production on this plant.

Table 11 gives a very useful comparison of capital charges for gas produced from various types of plant, and shows that these charges are substantially lower for a large refinery gas reforming plant than for even a large modern carburetted water gas plant.

Although the price per therm for the purified refinery gas is not as low as the price per therm for gas-making coal, and although there are no residuals to offset this cost, the considerably lower handling costs, labour costs and process costs far outweigh this disadvantage. This can be judged from the figures presented in Table 12, which gives some current costs for the reforming of refinery gas at Romford.

Table 11.—*Comparative Capital Charges.*

Type of Plant	Rated Output (Mill. ft³/day)	Annual Load Factor (Per cent)	Capital Charges (*d.*/therm)		
			Production Plant	Ancillary Plant	Total
1	2	3	4	5	6
Continuous vertical retorts	5·0 to 7·5	83	1·244	1·216	2·460
Coke ovens	5·0 to 7·5	83	0·979	1·175	2·154
Small C.O.G. plant	4·0	90	0·457	0·392	0·849
Large C.W.G. plant	24·0	90	0·247	0·301	0·548
Large reforming plant	36·0	90	0·210	0·091	0·301

Production plant costs include capital charges on the plant buildings.
Ancillary plant costs include capital charges in respect of coal- and coke-handling plants (where applicable) in addition to charges for exhausting, condensing and purifying plants.

Table 12.—*Costs for the Reforming of Refinery Gas*

	Cost of Gas Produced (*d.*/therm)	
1	2	
Capital Charges:		
Production plant	0·210	
Ancillary plant	0·091	
Refinery gas main	0·040	
		0·341
Process Charges:		
Labour costs	0·064	
Process and purification costs	0·126	
		0·190
Repairs and Maintenance		0·158
Total		0·689

The largest single item contributing to the total cost of gas into holder is, of course, the cost of the refinery gas feedstock per therm of gas produced, and in order to minimize this figure it is essential to secure and maintain the highest possible overall thermal efficiency on the reforming plant. This prompts the following analysis of the most important factors, which require close attention if minimum gas production costs are to be achieved.

(B) Requirements for the Production of the Cheapest Therm

HIGH THERMAL EFFICIENCIES:

(1) Reforming efficiency.
  (*a*) Conversion efficiency.
    (i) Maintenance of sound, active catalyst beds.
    (ii) Maximum conversion of hydrocarbons.
    (iii) Minimum production of carbon.
    (iv) Optimum temperatures and contact time with catalyst.
  (*b*) Minimum burner fuel consumption.
    (i) Reduction of radiation and convection losses.
    (ii) Reduction of excessive heat losses to waste-heat boiler and stack.
    (iii) Avoidance of frequent heat-raising (occasioned by changing over of units).
(2) Maximum cold enrichment addition.
  (*a*) Reduction of lean gas calorific value.
  (*b*) Reduction of cold enrichment calorific value.

FAVOURABLE OVERALL CONTROL OF PLANT:

(1) Maintain gas-making rates at optimum levels.
  (*a*) Divert surplus refinery gas for efficient use elsewhere.
  (*b*) Provide alternative feedstocks to cover against temporary deficits of refinery gas.
(2) Use of cheaper feedstocks.

Elementary though this analysis appears, each factor is of profound fundamental importance and has received

close scrutiny. They will be enlarged upon in the subsequent sections, making it possible to illustrate some of the more important features of plant control and operation.

VII THE REFORMING PLANT: THERMAL EFFICIENCIES

$$\textit{Conversion Efficiency} = \frac{\text{Lean Gas Thermal Output}}{\text{Process Gas Thermal Input}} \times 100$$

$$\textit{Reforming Efficiency} = \frac{\text{Lean Gas Thermal Output}}{\text{Process and Burner Gas Thermal Input}} \times 100$$

$$\textit{Overall Efficiency} = \frac{\text{Total Final Gas Thermal Output}}{\text{Total Thermal Input}} \times 100$$

The conversion efficiency is an artificial, but useful, concept. It takes no account of the thermal input of the steam, which reacts with the refinery gas. As all the process steam is raised on the plant boilers, however, the reforming efficiency does make the necessary allowance.

(A) Reforming Efficiency

The highest conversion and reforming efficiencies can only be obtained when the catalyst beds are maintained in a sound and active condition.

Catalyst Activity

The SIN type of "Onia-Gegi" catalyst in use in the reforming plant is of nickel-impregnated sillimanite in the form of extruded cylinders averaging 0·5 in. long and 0·4 in. diameter. The activity of the catalyst is due largely to the porous nature of the support material, which exposes a large proportion of the active catalyst constituent to the reactants. Although of a highly refractory nature, any overheating that might lead to fusion and glazing of the surface would cause a considerable loss of activity.

It is not easy to determine by chemical methods, in a reliable and satisfactory manner, the absolute activity of any sample of catalyst. Useful indications, however, are given by the following characteristics.

(1) Total nickel oxide content.
(2) Total nickel oxide which is easily reducible under normal plant operating conditions.
(3) Total nickel oxide which is soluble in boiling concentrated hydrochloric acid.

New catalyst, and samples that have been subjected to 8,000, 10,000, 11,000 and 14,000 working hours, have been examined in this fashion, and the results show that there is a gradual decline in all of these properties during the life of the catalyst. Spent material has been re-nickelled, however, and its activity fully restored.

The purchasing of refinery gas in the purified form, essentially free from hydrogen sulphide and organic sulphur compounds, was decided upon in the first place so that the 17-mile refinery gas main could be laid in mild steel instead of in cast iron. The three additional benefits derived are extremely valuable ones, namely,

(1) Maintenance of satisfactory catalyst activities and high plant efficiencies.
(2) Reduced purification costs.
(3) Consistently low level of organic sulphur in the reformed gas (below 0·5 gr/100 ft³).

Catalyst temperatures are normally within the range 650° to 820°C, and under these conditions the catalyst appears to withstand cyclic operations extremely well. In fact, the reactor catalyst beds were left quite undisturbed for the first two years of operation, and when they were screened at the end of the second year there was little evidence of any breakdown. The steam preheater catalyst beds were repeatedly disturbed by occasional "rough lighting" of the primary burner until the ignition pillars were installed, and this caused much of the catalyst to fall to the base of the vessel. In one particular case, when a unit was operated without a primary catalyst bed, tests showed that the conversion efficiency on this unit had fallen by 5·8 per cent and the reforming efficiency by 4·3 per cent.

The oxidation of the catalyst during the heating phase leaves it with a very low activity at the beginning of the conversion phase. By limiting the excess burner air to a minimum, the extent of oxidation is reduced, and a higher overall catalyst activity is obtained during the conversion period.

Conversion of Hydrocarbons

The theoretical conversion efficiency for complete cracking with steam lies between 120·0 and 127·5 per cent for the C_1 to C_4 hydrocarbons. In practice, although all the unsaturated hydrocarbons are completely cracked, there is normally a residual paraffin content of 2·0 to 7·0 per cent, of which 85·0 to 97·0 per cent is methane. Conditions that are favourable for more complete conversion of hydrocarbons tend also to be more conducive to thermal decomposition to carbon.

Experience at Romford has shown that, whereas it is impossible to achieve full hydrocarbon conversion, a closer approach to theoretical can be made provided that contact times with the catalyst are near optimum, and slightly higher proportions of process steam are used. Consequently, if a lower gas output is required, it is preferable to adjust the duration of the conversion period rather than reduce the instantaneous rates of flow of process gas and steam. Early plant operation was based on the use of 1·4 vol steam/vol carbon, but this has now been increased to 1·5 with beneficial results.

Carbon Production

Carbon production during the conversion phase is very low indeed, and often impossible to detect. Provided that the carbon is deposited on the chequer bricks or the catalyst, there is no loss of reforming efficiency, but if it is carried forward to the washbox then there is a thermal loss from the system. It is not possible on the Romford plant to arrange for the process refinery gas to by-pass the steam preheater chequer work without by-passing also the first catalyst bed. Nor is it possible to work at reduced temperatures in the steam preheater with compensating higher temperatures in the reactor without producing a surplus of steam above process requirements. Thus it is necessary to tolerate the small amount of thermal cracking that occurs.

One source of carbon production that has been remedied, however, is that arising from the partial combustion at the beginning of the heating phase of a small proportion of the process refinery gas, which tended to circulate back into the combustion chamber during the conversion phase. The diversion of about 15 per cent of the process steam through the combustion chamber gave a steady purge during the conversion period, which prevented the return of the process refinery gas.

Tests carried out on the plant show that under normal operating conditions, when producing about 35·0 mill. ft³/day of final gas, for every 1 mill. ft³ of lean gas pro-

duced, approximately 2·69 lb of carbon will leave the reactors and pass to the washboxes. Of this quantity, 2·59 lb will be removed in the washboxes and the scrubbers, and 0·10 lb will finally be filtered out in the oxide purifiers. The total quantity of 2·69 lb represents only 0·027 per cent of the carbon present in the process refinery gas, and is equivalent to a loss of about 20 therms of lean gas per day. The deposition of 3 lb/day of carbon in the oxide purifiers has caused back-pressure difficulties, however, and experiments are now being carried out to discover whether this finely divided carbon can economically be filtered out, or otherwise removed, before the gas enters the purifiers.

Contact Time with the Catalyst

For a refinery gas of given composition and with sound catalyst beds, the three most important factors effecting plant performance are catalyst temperatures, steam: carbon ratio, and contact time with catalyst.

All these factors are inextricably involved, and when the variations in feedstock composition and gas-making rates are also included the relative importance of each factor is very difficult to assess. What has emerged very clearly on the Romford plant is that variations in contact times and gas-making rates have a much greater effect on reforming efficiencies than variations in refinery gas calorific value within the range 1,000 to 2,000 B.t.u./ft³.

A series of tests was carefully planned, with the intention of holding certain variables constant in order to observe the effects of others. Firstly, a series of snap samples of lean gas were collected in evacuated bulbs over the whole of the conversion period of one cycle: 18 samples were taken, some at the outlet of the first catalyst bed and some at the outlet of the second bed. At the beginning and end of the conversion period, where the gas composition was known to change very rapidly, samples were collected at 10 s intervals. The results are shown in Figures 6 and 7,

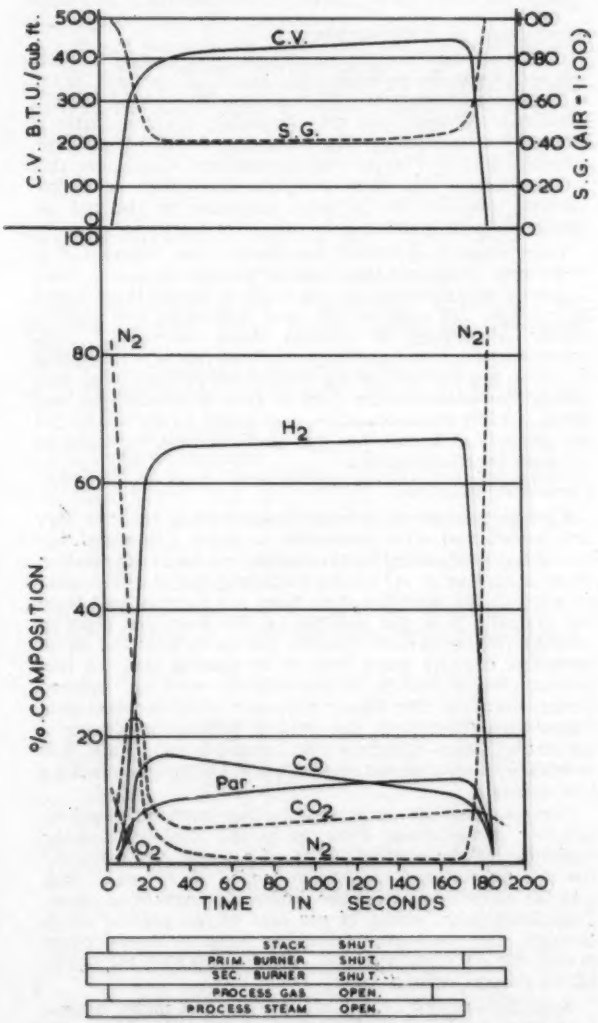

FIGURE 6.—*Composition of Lean Gas After First Catalyst Bed.*

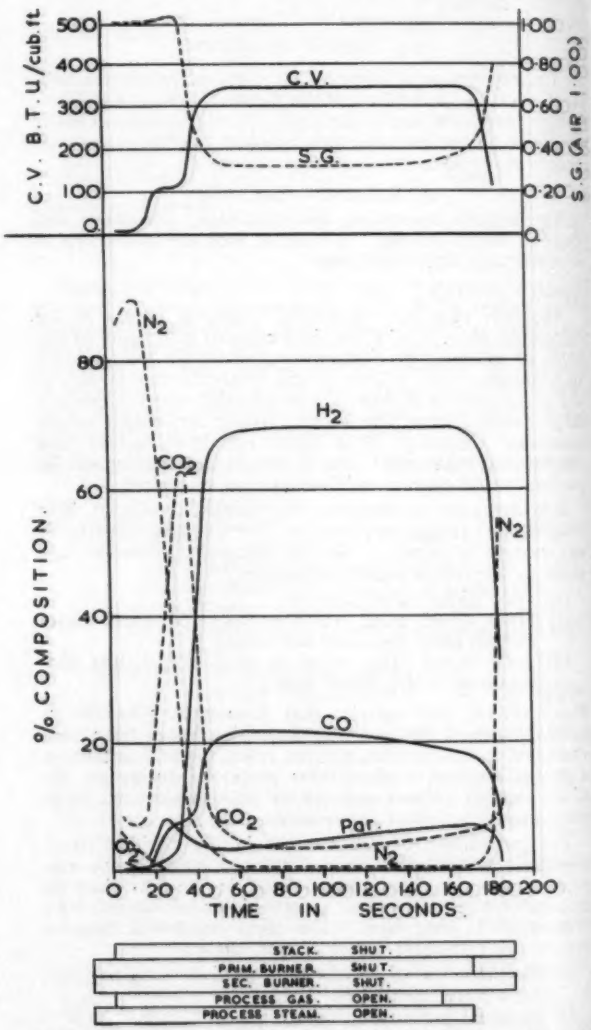

FIGURE 7.—*Composition of Lean Gas After Second Catalyst Bed.*

and give a clear insight into the nature of the reactions occurring during this phase of the cycle. It was clear that within 100 s of the opening of the process gas valve, the lean gas being produced was fairly representative of the average lean gases, and this point was selected as a suitable one for comparative tests under varying conditions.

Further tests were then performed when the refinery gas calorific value was 1,800 to 1,850 B.t.u./ft³, and with temperatures in the unit standardized as far as possible. The factors that were varied were the steam:carbon ratio and the contact time with the catalyst. The contact times quoted are the actual times, with full allowance made for the free space in the catalyst bed and the effect of temperature on the gaseous volumes. Limitations of space will not permit the presentation of all the basic data collected in this series of tests, but an examination of data derived from two of them will indicate how it was possible to derive some useful conclusions. With a knowledge (from orifice meters) of rates of flow of process gas and steam, together with analyses of the refinery gases and the lean gases, it was possible to draw up a mass balance, and thence derive certain figures that are shown graphically in Figure 8. Owing to the possible sources of error involved in calculating the mass balances, the absolute accuracy of these figures cannot be guaranteed, although the trends are reliably indicated.

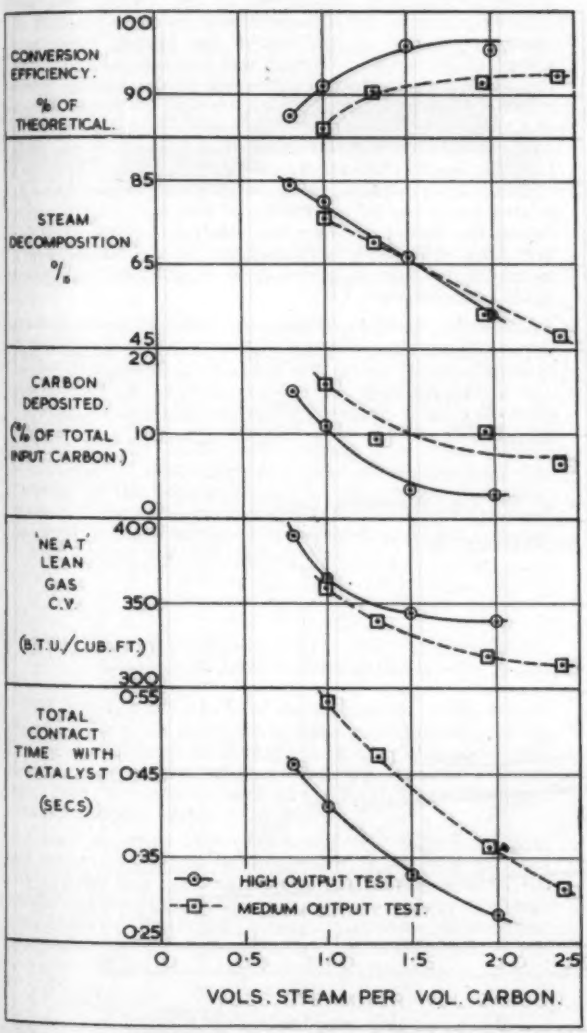

FIGURE 8.—*Effect of Various Steam: Carbon Ratios and Contact Times.*

The conclusions that have been drawn from a thorough analysis of all the data obtained are as follows:—

(1) For a given process gas rate:
As the steam rate is increased,
the steam:carbon ratio is increased,
the time contact is reduced,
the lean gas carbon monoxide and paraffin contents are lower,
the lean gas carbon dioxide and hydrogen contents are higher,
the lean gas calorific value and carbon:hydrogen ratio are lower,
carbon formation is lower,
steam decomposition is lower, and
conversion efficiency is higher.

(2) For a given steam:carbon ratio:
As the process gas and steam rates are increased,
the time contact is reduced,
the lean gas carbon dioxide and paraffin contents are higher,
the lean gas carbon monoxide and hydrogen contents are lower,
the lean gas calorific value and carbon:hydrogen ratio are higher,
carbon formation is lower,
steam decomposition is unaffected, and
conversion efficiency is higher..

(3) For a given contact time:
As the process gas rate is increased and the steam rate decreased,
the steam:carbon ratio is reduced,
the lean gas carbon dioxide and hydrogen contents are lower,
the lean gas carbon monoxide and paraffin contents are higher,
the lean gas calorific value and carbon:hydrogen ratio are higher, and
steam decomposition is higher.
For steam:carbon ratios below 1·5 and contact times above 0·40 s,
carbon formation is higher, and
conversion efficiency is lower.
For steam:carbon rations above 1·5 and contact times below 0·40 s,
carbon formation is lower, and
conversion efficiency is higher.

It is now customary practice to endeavour to operate with total contact times of 0·30 to 0·40 s, and with steam:carbon ratios of about 1·5. This has yielded very satisfactory results.

Minimum Consumption of Burner Fuel

The efficient insulation of the plant vessels, and the lagging of the waste-gas mains and the preheated blast mains has reduced radiation and convection losses to a minimum. The plant is normally operated in such a manner that waste-heat steam production just balances total steam requirements on the plant. Provided that the steam is utilized as efficiently as possible, heat losses to the waste-heat boiler are thereby minimized. The installation

of the air preheaters in the waste-gas mains between the waste-heat boilers and the common stack raises the temperature of the air blast to about 130°C and increases the reforming efficiency by 1·5 to 2·0 per cent for a relatively modest outlay.

By keeping high standards of mechanical maintenance, frequent changing over of units, involving unnecessary heat-raising, is minimized. Working units are planned to run continuously through the Winter period, but, as it is unnecessary to operate more than three units during the Summer months, it is possible to allot a six-week maintenance period to each unit in turn.

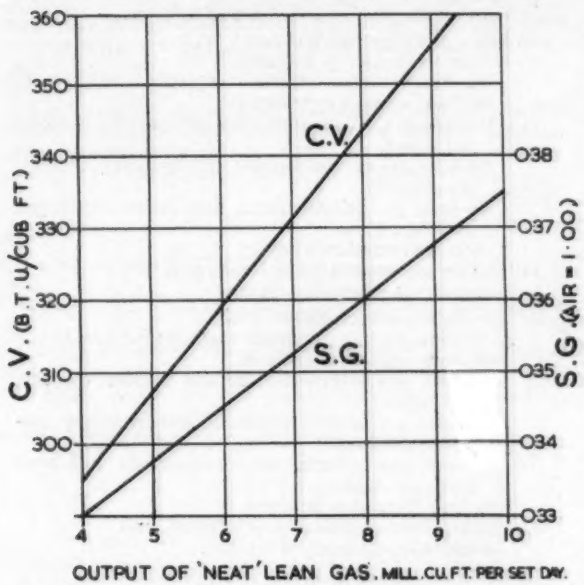

FIGURE 9.—*Effect of Gas Making Rates upon "Neat" Lean Gas Calorific Value and Specific Gravity.*

(B) OVERALL EFFICIENCY

The maximum addition of cold enrichment refinery gas at 100 per cent thermal efficiency assists in securing high overall efficiencies. This may be achieved by minimizing both the lean gas calorific value and also the cold enrichment calorific value.

Reduction of Lean Gas Calorific Value

It is necessary to strike a nice balance between such factors as hydrocarbon conversion and carbon formation if optimum efficiencies are to be maintained, but, as already shown, as the gas-making rates increase and contact times diminish, the calorific value of the neat lean gas rises even if the steam:carbon ratio is raised. This correlation is shown in Figure 9. Reduction of the average lean gas calorific value is, therefore, achieved by the admission of added inerts both at the end of the heating phase and during the blow-run. When it was realized, however, that the waste gases admitted at the end of the heating phase could contain as much as 15 to 20 p.p.m. of nitric oxide, it was necessary to restrict the admission of these inerts to such proportions that the nitric oxide content of the final lean gas would not exceed about 0·5 p.p.m. This was achieved by a schedule of make purge durations that was related to the rate of production of lean gas. Fortunately, during the blow-run, when the catalyst is being oxidized, very little nitric oxide is formed, and it was not necessary to curtail this portion of the cycle in order to limit nitric oxide concentrations.

Reduction of Cold Enrichment Calorific Value

The station has no direct control over the refinery gas calorific value, of course, but the addition of excess purification air means that cold enrichment can be carried out when required by refinery gas/air mixtures at lower calorific values.

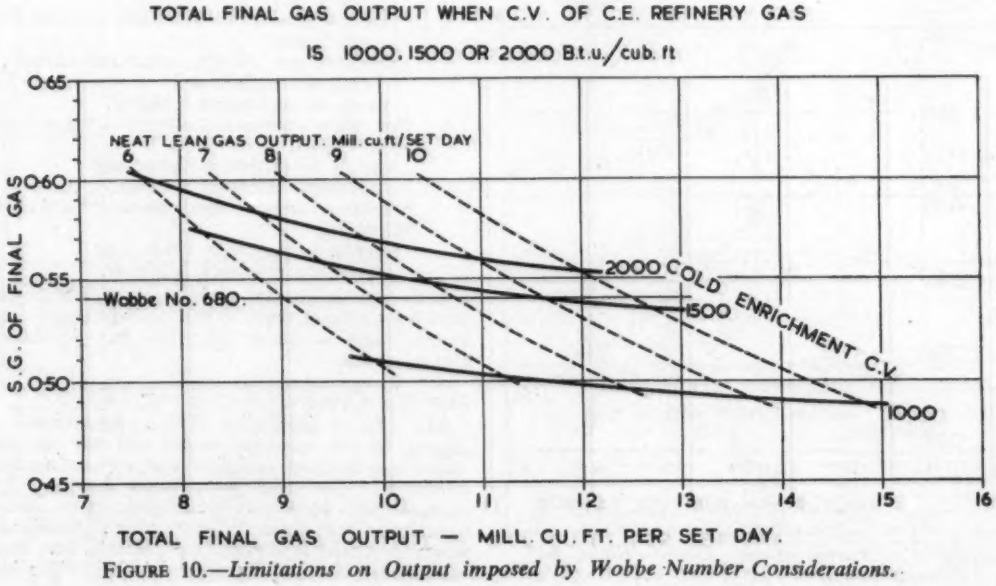

FIGURE 10.—*Limitations on Output imposed by Wobbe Number Considerations.*

The maximum addition either of blow-gas inerts or of purification air inerts is often limited, however, by specific gravity considerations. This is very clearly shown in Figure 10. This graph is based on the maximum addition of inerts, consistent with a nitric oxide content in the enriched gas no greater than 0·3 to 0·4 p.p.m. Once again, overall efficiency is maximized if the final gas specific gravity is brought as near as possible to the limits imposed by considerations of the Wobbe Number. Provided that the specific gravity is not permitted to exceed 0·54, then the Wobbe Number will always be above 680. Figure 10 shows that, for cold-enrichment refinery gas calorific values below 1,300 B.t.u./ft³, maximum inerts addition may safely be practised. For calorific values between 1,300 and 1,500 B.t.u./ft³, the addition of inerts must be restricted slightly at lower rates of gas making. For calorific values above 1,500 B.t.u./ft³, even further restrictions must be imposed, particularly at lower rates. A typical operating cycle is portrayed in Figure 11. The relative durations of the

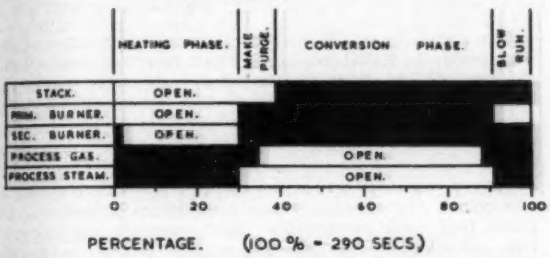

FIGURE 11.—*Reforming Plant: Typical Operating Cycle.*

heating phase and the conversion phase are adjusted in accordance with the output requirements simply by setting the necessary ratio on the blow and run shafts of the automatic operator. The duration of the make purge is laid down in an operating schedule and can be altered very quickly by means of a small cone clutch adjustment attached to the stack valve closing cam. For higher refinery gas calorific values and lower gas-making rates, the duration of the blow-run must be reduced by alterations to three of the cams on the blow and run shafts. Constant attention to these settings gives rewarding results in terms of both output and efficiencies.

VIII THE REFORMING PLANT: OVERALL ECONOMIC CONTROL

The previous sections have shown how the contributions made by the plant designers and the personnel responsible for plant operation have resulted in high efficiencies and low costs of gas production. Much of this success would have been unobtainable without the careful overall control exerted at higher levels in the Board.

Figure 12 shows how overall and reforming efficiencies are related to the rate of production of the final enriched gas and the lean gas respectively. An examination of the results achieved when operating steadily under optimum conditions at high rates of gas production showed that efficiencies of the following orders can be obtained:—

	Efficiency (per cent)
Conversion	113·5
Reforming	90·0
Overall	94·0

When this was realized, arrangements were made at the Board's Control-room that the available refinery gas should be so distributed between Romford and Beckton that the Romford plant would at all times be operating at optimum gas-making rates. This meant that the use of refinery gas at Beckton, either as cold enrichment for blue water gas or at times as refinery gas/air mixtures, had to absorb most of the fluctuations in the supply of refinery gas. Although this gave rise to problems at Beckton, the overall result was certainly beneficial to the Board, and was largely made possible by the highly developed grid main system in the Board's Area.

At the same time, Beckton was also using large quantities of commercial butane for cold enrichment purposes, and the higher specific gravities sometimes caused further problems, particularly during periods of lower gas demand. Plans that are being made for future developments are aimed at achieving the most flexible and economic usage of the variety of lighter hydrocarbon feedstocks that are generally becoming available in ever-increasing quantities. These plans must also satisfy the requirements of the type of seasonal load encountered in the Board's Area, and the conditions of supply for each feedstock. The construction of large reforming plants, capable of reforming P.F.D. and liquefied petroleum gases, at other stations of the Board, with increased facilities for the interchange of feedstocks between these stations, would make it possible to exert an over-riding control of reforming operations in such a way that outputs and efficiencies could always be kept as near to optimum conditions as practicable. When this is correctly correlated with gas production schedules for other types of plant, it should then be easier at all times to minimize the overall costs of gas production. Already, a 6 in. liquid-products pipeline has been constructed between

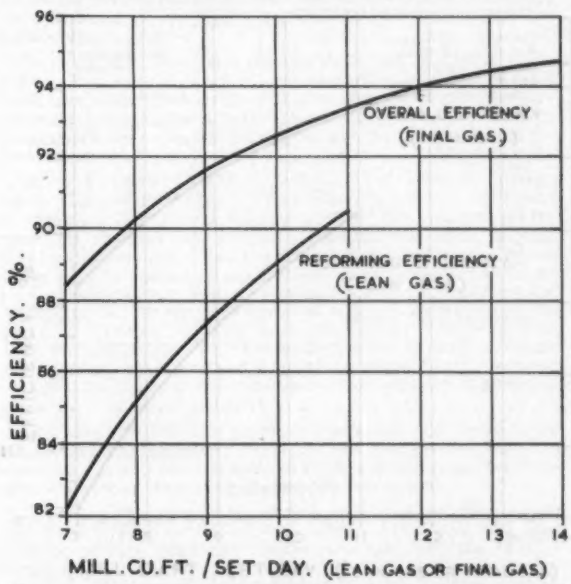

FIGURE 12.—*Correlation between Gas Making Rates and Thermal Efficiencies.*

Beckton Gas Works and Romford Gas Works, and evaporators suitable for dealing with liquid butane or propane have been installed at the Romford reforming plant. The 500 tons of liquefied petroleum gases that can be stocked in the

Beckton storage tanks thus become available for use on the Romford plant when warranted by circumstances. Although liquefied petroleum gases can be used very simply for cold enrichment purposes, the more effective technique would be to reform them to a lean gas, if this can be done with acceptable efficiencies, and use the refinery gases (with lower calorific values and specific gravities) for cold enrichment.

Butane and propane are feedstocks that the gas industry cannot afford to ignore. The future for liquid methane, on the other hand, cannot be visualized so clearly at this stage. If the large-scale importation of methane can be achieved, then the Canvey Island Methane Terminal, and the mains linking it with Romford and Beckton, may well prove to be the starting-point for a more elaborate grid, extending further over the Board's Area, or even into other Gas Boards' Areas.

TABLE 13.—*Reforming Plant Results for the Year 1959-60.*

	Mill. ft³	Calorific Value	Therms
1	2	3	4
TOTAL INPUT (Therms)			
Refinery gas	—	—	47,088,610
Methane	—	—	4,909,984
P.F.D.	—	—	13,727
Pilot burner gas	—	—	1,743
Total	—	—	52,014,064
TOTAL OUTPUT			
Lean gas	7,533	310	23,327,380
Purification air	284	—	—
Cold enrichment	1,842	1,363	25,102,873
Final gas	9,659	501	48,430,253
Total set days worked	—	892	
Average lean gas make per set day	8,445		
Average Final gas make per set day	10,828		
Conversion efficiency	110·5 per cent		
Reforming efficiency	86·7 per cent		
Overall efficiency	93·1 per cent		
Process steam usage (lb thou. ft³ final gas)	19·5		
	Lean gas	Final gas	
GAS ANALYSES :			
CO_2	8·9	7·1	
O_2	0·2	0·4	
CnHm	0·0	1·8	
H_2	61·4	53·0	
CO	14·2	11·9	
CH_4	4·8	3·3	
C_2H_6	0·4	12·2	
N_2	10·1	10·3	
	100·0	100·0	
Specific gravity (Air=1·00)	0·450	0·536	

P.F.D. is a less-refined and slightly cheaper feedstock than refinery and liquefied petroleum gases. It is, therefore, most suitable for use on the reforming plant burners, releasing as it does increased quantities of refinery gas for use either at Romford or elsewhere. Thus the use of refinery gas, liquefied petroleum gases and P.F.D., in suitable portions, can confer an extraordinarily high degree of flexibility, with very beneficial financial results.

This section is concluded by the presentation in Table 13 of the results achieved during the 12-month period 1959-60. While examining these results, it should be remembered that this period includes operation during a hot summer on relatively low gas-making rates, and experimental operation with P.F.D. and methane.

IX CONCLUSIONS

The successes, in the first three years of operation, of the new plants at Romford, and in particular the refinery gas reforming plant, have justified decisions taken five or six years ago, and have influenced more recent deliberations on the possible construction of additional plants of this type elsewhere. Manufacturers have been challenged to design plants that are low in capital cost, which offer a high degree of reliability and which can operate with satisfactory efficiencies over a wider range of different feedstocks. In order that such omnivorous plants may be exploited to best advantage, it is further necessary to provide the facilities for mobilizing the available feedstocks in such a way that they may be utilized wherever circumstances require at any given time, and in the most economic manner. The trend from rail and sea transport towards road transport, and more recently towards pipeline transport, is symptomatic of the desire for greater flexibility, and may well herald the development of a more extensive distributive grid system for raw materials.

Acknowledgments

The Author is grateful to the Chairman, Deputy Chairman and Chief Engineer of the North Thames Gas Board for their encouragement and their permission to present this paper. Acknowledgment is also due to all his colleagues who have contributed so helpfully, in one way or another, towards the collection and preparation of the necessary material.

PRESENTATION, DISCUSSION AND REPLY

Presentation

Mr. D. R. Coote presented his paper and summarized its contents.

Discussion

Dr. A. E. Haffner (Southampton ; Member and Chief Engineer, Southern Gas Board) :—When Mr. Coote, a former colleague, invited me to open the discussion, he modestly asked me to take into account that this paper was the first he had ever presented to a technical body. All of us must have been impressed by the level of technical and scientific sophistication displayed by the Author.

The " Romford " paper by Dr. J. Burns, G.M., and Mr. E. R. Stewart, presented to the Institution in 1959, is well remembered*. Mr. Coote now crowds into 16 very readable pages an account of the practical experience in operating this unusual works, with particular reference to the cyclic catalytic units that were installed there some three years ago. But it is much more than an account of an efficiently operated works. In spite of maintaining production at very high levels, opportunity has been taken to carry out a systematic investigation into the variables of contact time, the carbon : steam ratios, and process rates. There seems here to be an echo of the classic work that Dr. F. J. Dent, O.B.E., did so many

* The Romford Reforming Plant. Burns, J., and Stewart, E. R. *Inst. Gas Eng. Comm.* 550.

years ago in connexion with water gas plant ; work that has borne fruit in the very high efficiencies and outputs achieved subsequently by water gas plants.

The work that Mr. Coote has been doing is just the sort of work that is needed in all parts of the country where these new plants are being operated without the background of two or three generations of successful operation, such as coal carbonization had. It is a pattern of work that should be going on all over the country, with cross-communication and papers given and visits paid to each other's plant. This paper sets a fine example, and I hope that the way Mr. Coote has carried out these tests for optimization of the results will be followed as a model by other people.

It is not going to be possible for me to avoid referring to a rival works at Southampton, where nearly four years ago the first refinery gas was received and reformed in the fuel beds of the three existing water gas generators. In the meantime, two Onia-Gegi units, similar to those at Romford, were being constructed and went to work a few weeks after the Romfort unit. The delay in construction led to a number of what we think are improvements being introduced ; for example, the catalyst was in two beds, not by way of improvization, but two beds all in the same reactor. There were two or three disadvantages. The only space then available to us was that occupied by three small water gas generators with a total capacity of about 3 mill. ft³, and into this small space has been installed these two units which, potentially, can make 28 mill ft³. The Southampton plant is designed to cover a wider range of feedstocks than is the case at Romford. Its chimney height is sufficient for it to be able to take the highest sulphur feedstock. It can and has used virgin naphtha both on the blow and on the make, but, of course, the plant is normally on refinery gas. Outputs of 4 mill. ft³/d per unit have been obtained with medium fuel oil, 6 mill. ft³ with virgin naphtha, and 14 mill. ft³ with refinery gas if adjusted to 500 Btu/ft³.

These high outputs with refinery gas were not obtained at first because our refinery gas is not a premium grade, but contains up to 2 per cent of hydrogen sulphide. The output was expected to be 8 mill. ft³/d from these plants with this crude refinery gas, but proved to be only 4 mill. ft³/d because of the marked effect on catalytic activity affecting not only the output of lean gas, but also its calorific value. This has far-reaching consequences on the amount of refinery gas that can be added by cold enrichment. By collaboration with the contractors, however, a system of refinery gas purifiers was rapidly installed, and the effect on the Onia-Gegi units was sensational. There was not only, at first, a doubling of the output, but, subsequently, more than a trebling of the output just by the removal of hydrogen sulphide. The story of these automatically and frequently rotated purifiers is not for today, but must wait until a few remaining perplexities about the mechanism of purification under these special conditions have been disentangled. In spite of these academic questions, in the meantime, the refinery gas is satisfactorily purified, enabling high outputs to be attained.

I have said that there are two layers of catalyst in the Southampton reactors ; we have settled down to the upper one being magnesite-based and the lower sillimanite-based, a compromise that allows refinery gas and virgin naphtha to be efficiently reformed. We need also to have two wash boxes per set, the second one before the waste-heat boiler for use when fuel oil is being gasified.

Mr. Coote refers to the regenerative Onia-Gegi plant used for naphtha gasification. The Southampton plants, and also the Southern Gas Board's two Portsmouth plants, are all self-steaming and there has been no real difficulty over the last few years in handling these attractive feedstocks. The last self-steaming Onia-Gegi unit installed at Portsmouth is equipped to deal with naphtha only, and it went smoothly to work to produce more than its declared output.

Unlike at Romford, Southampton retained some coal gas, not out of sheer sentiment, but for three reasons : First of all, unlike at Romford, the coal is seaborne and from the Durham coal fields, and there is locally an unsatisfied coke demand, which circumstance would otherwise have meant the transport of coke at least 30 miles from another works. More subtly, however, the low-gravity coal gas allowed, in effect, more ballasted refinery gas to be sent out without upsetting combustion characteristics.

Apart from the Onia-Gegi plant, Southampton has not obtained as great productivity per man as Romford, because we still have some coal gas and the need to purify refinery gas and manufactured gases.

It interested me to calculate the output of therms/man per year at Romford. Assuming a 75 per cent load factor, this figure amounts to 440,000 therms. This is about 10 times greater than the figure shown by the North Thames Gas Board in 1959-60. Looking at it nationally, it would need only 35 Romfords to meet the needs of the whole industry. These 35 works would need only 6,000 instead of 45,000 men. I put it in this way not to spread alarm or elation, but to show what is the real achievement of Romford. In another paper at this Meeting, a production index is quoted by the Russian author A. P. Agishev of 1·8 mill. therms/man per year in the Soviet gas industry. This is only four times that at Romford, but this was based upon natural gas, and we had almost overlooked the need for production men at all in the case of natural gas.

Of course, all works in the country are not within reach of such a bountiful supply of refinery gas or natural gas. Wherever a works is located, there are plenty of local disadvantages, so let us exploit to the full any advantages, just as Romford has done.

Outputs of plants are not only dependent on the low calorific value of the lean gas, but the calorific value, composition and specific gravity of the refinery gas. It is interesting to compare Romford with Hamburg, which has such a high hydrogen content in its refinery gas that it can adopt a high-pressure, continuous catalytic authothermic reforming process without the nitrogen introduced by the air being a disadvantage. In Harrison, New Jersey, I was told that though the U.G.I. continuous catalytic reforming plant could produce 10 mill. ft³/d of lean gas, this could be enriched up to 557 Btu/ft³ with natural gas, and the combustion characteristics could permit the further addition of methane/air to make a total output, including associated gases, of 40 mill. ft³/d. More than three-quarters of this is really "cheating", though it still can be regarded as the output associated with a particular plant.

I have not succeeded in escaping becoming involved in too detailed a comparison of Southampton and Romford. This I particularly wanted to avoid because Mr. Fairman, of Southampton, who is steeped in the subject, hopes to be able to enter into the discussion.

We thank Mr. Coote for a remarkable account of a remarkable works. It is not only a record of day-to-day operation of plant detail and achievements ; there is also an account of some very systematic investigations, with plenty of evidence of original thought. If this is the first paper given by Mr. Coote, let it be the first of many.

Mr. J. E. Davis, O.B.E. (Croydon ; Chief Technical Officer, South Eastern Gas Board) :—There are three points I should like to make on Mr. Coote's excellent paper. The first one is very much the same as that which Dr. Haffner has made so well. It is an ideal that one sometimes dreams about, and it is, therefore, probably unattainable, that, in going on to a novel process, we start off with really adequate information about the chemistry and physics of all the reactions involved and full knowledge of the precision of control which we can, in fact, impose. Normally, however, the time required for such exhaustive studies is not available and one has to be content with a knowledge of pilot plant operation and the confidence that experience will provide the opportunity to learn. This is what happens.

Sometimes, in the early stages of operation, one learns rather rapidly and has experiences that are not pleasant but useful in teaching. Sometimes, one gets out of the difficulties still not completely understanding exactly what one has gained.

There are two ways of assessing a novel process. One has to put things right as they go wrong, and out of this there may grow a body of hypothesis and belief—quite sincerely held belief—which builds up into custom, but still without a basic understanding. This is unfortunate. Mr. Coote has taken a sounder line. His paper does not contain any theorizing ; it does contain results of a lot of very careful and accurate measurements, forming the basis of what will be sound understanding in the future. It is just this kind of thing that we must try to do with every innovation that comes, to build up on the basis of careful measurement careful records, in order that the many operators who are involved in new projects can come together, exchange views and really come to understand what it is they are doing.

The second point is a matter of comparison, or, rather, contrast. There is a basic difference between the Romford plant and the installation at the Isle of Grain, which some members may have seen and some will be seeing. As Mr. Coote points out, the capital cost of the Romford plant was very low. On the other hand, the raw material is a specification material and, therefore, it is not so cheap. It happens that, at the Isle of Grain, the raw material was obtainable at about half the price of the specification raw material at Romford. To make use of it, a higher capital investment is necessary, and, indeed, the Isle of Grain plant is more expensive per unit of output. There is little to choose between the overall costs of the final gas, and it is quite pointless to argue about which of the two policies is the more appropriate. It is a difficult problem to solve, in this and in many other connexions, whether one should go for specification raw material of high cost and limited availability, but with low capital for plant, or for a wide range of raw materials of lower cost and readier availability, but with a higher capital commitment. The best solution is different in different cases, and judgment on the merits of each individual case is by no means easy.

My third point relates to Figure 10 of the paper. The object of town gas manufacture is not merely to make a combustible gas, but to turn a raw material into a specification refined fuel. The specification for G4 gas fixes the upper limit of specific gravity at 0·51, and Figure 10 shows that this cannot be obtained from a refinery gas of more than about 1,200 Btu/ft^3, unless some carbon is rejected from the system, probably in the form of carbon dioxide. I regard this as an exceedingly important point, because, with the variety of processes now available for gas manufacture, and with a possible future trend towards calorific values and flame speeds different from those to which we are accustomed and for which gas appliances were originally designed, there is great need to exert discipline on the manufacturing side in taking advantage of all these new liberties if we are to give the standard of service upon which the whole of our business must rest. After all, it is not only what it costs at the works that matters : the biggest and most important factor in prosperity of the industry is an increasing consumption per consumer. This is going to be gained through service, and gas quality is not today to be regarded merely as a fancy extra, but as something absolutely imperative. I am convinced that we must design new processes and new installations, tailor-made for the production of a gas of specified quality as a prime requirement.

Mr. I. H. Phillipps (London ; Humphreys and Glasgow, Limited) :—Starting from the performance figures that have been so ably presented by Mr. Coote, I should like to make two points in connexion with the gas reforming plant, both concerned with the overall conversion efficiency. The first is on the use of two beds of catalyst arranged in series ; the second is the incorporation of air preheaters after the waste-heat boilers.

In 1956, when the design of the Romford plant was accepted by the North Thames Gas Board, it included only a single catalyst bed. Process development was going on at the time, based on the theoretical merits of dividing the bed into two, and, shortly after we had started work on the detailed design of the Romford plant, it seemed that these experiments with the two-bed catalyst development work were successful. Fortunately, it was not too late to incorporate the changes into the Romford design, so it was agreed to do so. This was a good thing because in the result, as the figures given by Mr. Coote show, the overall plant efficiency reached some 3 to 4 per cent higher than had originally been anticipated.

I think that it might be of interest to describe briefly how this very substantial improvement is brought about. I should like to stress immediately that it applies only to the reforming of gases and light hydrocarbons, and not to the gasification of heavy oils.

When reforming gaseous hydrocarbons, there is virtually no carbon deposited within the catalyst bed during the " run " phase of the cycle, and therefore the whole of the heat required for the reaction must be replaced from the heating gases during the heating phase. Putting in the heat in this way presents certain difficulties because there are upper and lower limits to the temperature at which one can run a catalyst bed, and, therefore, there is a maximum temperature drop in the heating gases as they go through the catalyst bed. This drop in temperature fixes the quantity of heating gases required, and, hence, the plant efficiency. If, however, the catalyst bed can be divided into two, not necessarily increasing the quantity of catalyst, and the blow gases then reheated in between these two layers, the gases can twice be used as a heat carrier. They go through the temperature range twice, and their heat can be extracted twice at the cost of merely topping up the temperature in between the two stages. This calls for a lower volume of waste gases for a given heat input into the catalyst. The gases are, however, at virtually the same final temperature, and there is a resulting saving in heating fuel and a corresponding increase in overall efficiency.

A further advantage of the two-bed design is that it allows the temperature of each bed to be chosen to suit the type of feedstock used ; for example, when reforming gases containing a high proportion of unsaturated hydrocarbons. This cyclic process has, incidentally, the great merit that it can handle very high percentages of unsaturated hydrocarbons. On occasions, we have had to reform feedstocks with as much as 30 per cent of unsaturated hydrocarbons. When this is being done, it pays to have a lower temperature in the first bed and to have a relatively higher temperature in the second bed. Obviously, this can be brought about only when the bed is divided into two.

Dr. Haffner has drawn attention to the fact that at Southampton there has been a further advance and the two beds are now located in the same reactor. This gives a more compact plant arrangement and also a number of other advantages. All new plants nowadays are on this basis.

The other matter I should like to discuss is that of the incorporation of air preheaters. Mr. Coote has produced figures that show that these make a very substantial contribution to the overall efficiency. He gives figures of 1·5 to 2 per cent. I thought it would be of interest, therefore, to abstract the actual associated capital cost that accompanies the inclusion of the preheaters and to show the rate of return. If one allows for everything—heat exchangers, lagging, foundations and the need for slightly longer and larger air mains—the capital cost of this equipment is just less than £25,000. Taking the plant load factor indicated by Mr. Coote, and an assumed cost for refinery gas feedstock, it may be calculated that the whole investment is recovered in a period somewhere between 18 months and two years.

I should like to make a final point : that the merit of including air preheaters is tied up very much with the use of low-sulphur fuel. This could not be done with a plant running on heavy oil, because the high sulphur content of the heavy oil would require that one had to keep up the stack temperature to avoid corrosion. With purified refinery gas, one may, obviously, decrease the stack temperature without this danger. The Romford plant is further ideal for the incorporation of these preheaters in that the steam pressure is high and, therefore, the waste-heat boiler outlet temperature is high. Everyone knows that the low-sulphur fuels now available offer many advantages. Mr. Coote, in separating out the performance of the preheaters, has underlined and pin-pointed one such advantage, which is, perhaps, not always seen so readily.

Mr. E. R. Stewart (Station Engineer, Romford Gas Works, North Thames Gas Board) :—Having been associated with Mr. Coote during the last three years, I would like to add my tribute to those of previous speakers, in complimenting him on a paper covering the operational side of the Romford plant. I should also like to express my appreciation of the services he has given during that time, particularly on the plant testing and the experimental work carried out, including the interpretation of the results obtained.

This paper adds a fund of information to that provided in the first paper on the Romford plant, and its value is in the practical data included.

The plant at Romford has been mentioned by previous speakers and its satisfactory operation discussed, and I do not intend to go far into this. There is, however, a point I should like to make in connexion with the catalytic type of plant in general, that is, that it still has its problems. At the Romford plant, we have had difficulty with thermal cracking of the feedstock, and some carbon formation is always liable to occur when process rates and operating conditions are changed, particularly when reforming high-calorific value gases.

We need a lot more information on the catalyst in determining its loss of activity, and its probable life, at any given time during its use, and, with the catalytic oil gas plant in particular, we need a

more robust and substantial catalytic material that will withstand the effects of steam or mishandling without destruction.

Mr. Coote, in his introduction, has mentioned the use of butane as an additional feedstock to supplement refinery gas input. During the last month or so, the first runs on butane have been tried. Increasing quantities were used for reforming, admitted with the refinery gas, and we have now had as much as 40 per cent admixture of butane with refinery gas for reforming.

We have used it for cold enrichment up to 90 per cent of the total enrichment requirement, without any difficulties arising. The Kent " Sigma " calorific value controller has operated quite satisfactorily on this high-calorific value gas, and the Wobbe index, although slightly lower, has been well within our normal limits.

Butane, as is known, has a calorific value of 3,200 Btu/ft³, and specific gravity of 2·01, and, therefore, its suitability for reforming needs careful examination. However, its use coincided with a period when gases of low calorific value were being received from the refineries, and the 40 per cent butane admission that we have practised so far has not increased the mixture for reforming much above 2,000 Btu/ft³. We have accepted gases in excess of this calorific value before, and, in consequence, we shall have to continue using butane with incoming higher-calorific value gases to find its effect at the high levels.

There is no doubt from the results that we have already obtained that the Romford plant can satisfactorily deal with 160 tons/d of butane in addition to the refinery gas, thus increasing the plant output by some 12 mill. ft³/d, when required. The butane admission will make a valuable standby and an addition to the feedstock available from the refineries to meet the high demands that are anticipated during the winter of 1961-62.

Mr. Coote has looked a little into the future, and I should like to do the same, particularly with reference to the possible importation of liquid methane. We look forward to this with very keen anticipation. It is well known that, both for reforming and enrichment, the lower the calorific value of the feedstock, the better the results obtained. Natural gas, with a calorific value of only 1,100 Btu/ft³, produces high volumes of final gas per unit of plant, at high efficiencies of operation. The final gas has a low carbon monoxide content, certainly less than 10 per cent without carbon monoxide conversion, and, most attractive of all, the cost per therm into holder would be only 7¾*d*., based on the costs given in Tables 11 and 12 of the paper and with liquid methane being received into the country at 6½*d*./therm. This is a very attractive figure and one, I am sure, that will make the Board's sales and service staff really smile. On this optimistic note, and in conclusion, I should like once more to congratulate Mr. Coote on his excellent paper.

Mr. J. R. Fairman (Assistant Station Engineer, Southampton Works, Southern Gas Board) :—Mr. Coote in his very interesting paper has shown that gas production at Romford has undergone a startling transformation in the past four years. Dr. Haffner has indicated that, in the same period of time, a similar remarkable development in capacity has taken place at Southampton Works. Both works receive refinery gas through pipelines from nearby refineries, but there are a number of interesting differences between the two works and their production plants and techniques of reforming refinery gas.

At Southampton, coal-carbonizing plant with a capacity of 4·5 mill. ft³/d has been retained and is worked as a base-load plant producing coke needed for local sales and for the carburetted water gas plant.

Another difference is that fuel-bed reforming of refinery gas is practised at Southampton on the three 2·5 mill. ft³/d carburetted water gas sets, each of which is able to produce about 4 mill. ft³/d of final gas from this feedstock, at an efficiency of nearly 85 per cent.

These sets are also able to use virgin naphtha (P.F.D.) for enrichment and reforming. As at Romford, we have had similar very good results and have complete confidence in the ability of the sets to take virgin naphtha if insufficient refinery gas is available, or at times of peak load. The output per set with this feedstock is 3 mill. ft³/d.

Naphthalene formation with virgin naphtha can be a problem, and I note that Mr. Coote comments on the use of 1 gal of gas oil per cycle through the centre of the make-spray, which is, presumably, to give a solvent tar to prevent build-up of deposits. I should like to know if this has been a completely successful method of dealing with the formation of naphthalene, or whether any other sprays or clearing techniques are employed.

The Onia-Gegi gasification plants at Southampton normally operate on refinery gas for process and heating purposes, but virgin naphtha burners have recently been installed and tests have shown that the sulphur content of the naphtha, 0·03 to 0·08 per cent, does not affect the efficiency of reforming.

The flexibility of the catalytic plants with regard to feedstocks is one of their endearing features, and Mr. Coote makes reference to the 6 in. diameter pipeline now available for conveying liquefied petroleum gas from Beckton to Romford when necessary.

Our own use of liquefied petroleum gas is by a rather different arrangement, using the existing refinery gas pipeline, into which butane may be vaporized at the refinery. These facilities were commissioned in November, 1960, and the installation has a capacity of 40,000 therms/d.

Proportional control ensures that the dew-point of the butane is not reached in the pipeline, and the increased calorific value of the mixture provides a valuable addition to the carrying capacity of the main at the time it is most required.

The section of the paper dealing with the results and performance of the reforming plant at Romford commands our admiration, as it shows the great care that has been taken to establish and maintain optimum operating conditions. Some of the ancillary plant installed (e.g., air heaters) are not justified at Southampton, because a satisfactory return cannot be shown on the capital outlay by the resultant increase in efficiency.

Dr. Haffner has mentioned that one of the major differences in the composition of the refinery gas supplied to Southampton is that it can contain up to 2 per cent of hydrogen sulphide, and pre-purification of all refinery gas used for process and heating on the catalytic reforming plants is necessary. This is carried out to a standard of less than 3 p.p.m., and it has been shown, by experience, that, at this concentration, catalyst activity is not affected.

At about 50 p.p.m., there are indications that activity is affected, and, by 300 p.p.m., catalytic reforming is severely affected.

Catalyst poisoning may be observed by an increase in the calorific value of the lean gas, a rise in catalyst temperatures, and a fall in the pH of washer and scrubber effluent. On the very infrequent occasions when a break-through of hydrogen sulphide in the gas to the sets has occurred, the catalyst does not appear to have suffered any permanent damage, and its full activity is apparently restored when clean gas has been supplied.

Organic sulphur in the refinery gas from Fawley is present at concentrations of 2·5 to 6 gr/100 ft³, and in the lean gas this is reduced to 0·3 to 1·5 gr/100 ft³. The organic sulphur has not affected the catalyst activity at these concentrations.

Mr. Coote mentions the danger of physical breakdown of the magnesite-based catalyst by partial hydration with steam at about 300°C. This happened at Southampton and revealed itself when a set was opened up for annual internal examination.

During the cooling period, a steam valve on the secondary burner supply at the top of the reactor had been leaking, and this, with falling temperatures, gave the required conditions.

The lesson learned is obvious.

The Author's Figure 4 is a most satisfactory graph of reforming efficiency, and he mentions that some of the catalyst had been in use for over 16,000 working hours.

Does this maintenance of performance agree with laboratory tests, which, in Section VII, show that there is a gradual decline in the catalyst properties that determine activity ? or has improved plant control masked any deterioration that might have occurred?

The final point I should like to comment on is carbon black formation. The Southampton plant is constructed so that the process refinery gas is admitted to the top of the steam preheater ; therefore, it by-passes the preheater checkers. A modification has been made to the process steam connexions, so that about 50 per cent of the steam still passes through these checkers and prevents any refinery gas drifting back to the combustion chamber ; it avoids also partial combustion at the beginning of the heating phase, and retains a useful degree of superheat for the process steam.

Formation of carbon black has to be constantly guarded against in day-to-day operation, especially when the characteristics of the

refinery gas are changing. Routine tests are taken by impingement of a stream of gas on a piece of filter paper at the inlet to the washer, but quantitative measurements of the order of 2 to 3 lb/mill. ft^3 are quite difficult to achieve, and I should appreciate details of the technique employed at Romford, and the accuracy obtained.

Mr. Coote has given a valuable series of working results, and his conclusions are of great significance.

Romford and Southampton have had, and no doubt will have, many similar problems, and my colleagues and I are indeed grateful to the Author for this most helpful record of the work on catalytic reforming.

Written Reply

The Author, in reply, wrote :—Dr. Haffner's comments have strongly reinforced the Author's own observations relating to the undoubted advantages of employing a feedstock almost entirely free from sulphur. In the Author's view, it is also cheaper to purify the refinery gas at high pressures and subsequently reap the benefits of greater plant outputs and efficiencies than to purify the product gas derived from a sulphur-bearing feedstock.

The idea of employing two different beds of catalyst in the same unit in order to facilitate the alternative gasification of primary flash distillate or refinery gas is an appealing one. This experiment can be judged successful presumably only if outputs and efficiencies with either feedstock do not suffer unduly, and the working life and effectiveness of the two catalysts are not excessively diminished. One wonders, however, whether this compromise will eventually prove worth while.

In considering the manning of the three plants at Romford, it should be realized that the total shiftwork strength is the minimum that will ensure the safe and rapid execution of starting-up, shutting-down and emergency routines. Any further additions of automatic control or instrumentation will not permit a reduction of manpower. Such controls are not only costly to install, but they can sometimes prove expensive to maintain satisfactorily, and for this reason instrumentation at Romford has not been extended beyond the point of practicability.

Mr. Davis has raised two most interesting comparisons between the Romford plant and the Isle of Grain installation. Firstly, as Mr. Davis states, the Romford plant is lower in capital cost than the Isle of Grain plant, but utilizes a sulphur-free feedstock that is a little more expensive than the cruder feedstocks employed at Grain. He has rightly emphasized that, although the choice between these alternatives may appear a very difficult one, local circumstances will often suggest the better solution. Projects involving heavy capital expenditure should be embarked upon only after the most critical examination of all the circumstances. Plants designed to handle the cheapest feedstocks have problems that cannot lightly be dismissed. These cheaper and less-refined fuels, with higher carbon to hydrogen ratios, require a higher degree of reforming. The penalities incurred by using such materials are more expensive production and purification plants, more difficult plant control and greater manpower requirements, the production of embarrassing residuals, and more modest outputs and efficiences. It has been argued elsewhere that it is unsound to endeavour to accomplish in the same plant the catalytic gasification of heavy oils and the simultaneous or subsequent conversion of the deposited carbon into water gas. Might not an extension of the same argument suggest that it is expecting too much of a plant to handle efficiently too wide a range of feedstocks? The North Thames Gas Board, by paying the additional premium for the purification of the feedstock supplied, gained benefits in many directions. These sulphur compounds would otherwise have had to be removed at Romford, either from the refinery gas or from the final gas, but the purification of the feedstock at source enabled the refinery gas main to be laid in steel at a much lower cost than for cast iron. Moreover, being able to operate at very much higher pressures, it provided invaluable storage capacity at no extra cost. Fortunately, at Romford it was possible to install a reforming plant that was low in capital cost and in labour requirements, and which utilized this sulphur-free raw material with a high degree of efficiency and reliability. The plant and the process were simple, easily controlled, and ideally suited to the alternative use of liquefied natural gas, butane and primary flash distillate. The plant and the feedstock are an excellent match, and the success of the decision has been amply demonstrated by the fact that the total cost of gas production is the lowest for any plant of the North Thames Gas Board.

Mr. Davis has also commented on gas characteristics, and has suggested that if too great a liberty is taken with the Wobbe number of the gas being distributed an unfavourable consumer reaction may result. A G4 gas, having an optimum Wobbe number of 730, will give satisfactory performance on appliances within range of at least $\pm$ 5 per cent from this value. Mr. Davis is right to emphasize the need for discipline, and when operating at the extremes of this range of Wobbe number considerable vigilance and careful control must be maintained at all times.

The Author is indebted to Mr. Phillipps for his valuable contributions relating to the advantages of arranging the catalyst in two separate beds with a secondary burner situated between them, and the great benefits to be derived from the installation of air pre-heaters. The latter point adds further weight to the arguments in favour of a sulphur-free feedstock.

Mr. Stewart, one of the co-authors of the first paper to deal with the Romford plant*, has contributed many features of more recent interest, which serve to bring the present paper quite up to date.

Having had considerable experience with similar plants at Southampton, Mr. Fairman has naturally asked some very detailed practical questions. When reforming primary flash distillate on the carburetted water gas plant at Romford, and injecting 1 gal of gas-oil/cycle into the carburettor, after an operating period of three months there was no sign of blockage between the grate rings, no difficulty in the washbox or condenser, and no greater deposits in the back-run main than would have occurred with the normal use of gas oil. No additional flushing sprays were installed, but regular addition of a surface activating agent to the system was initiated in order to break down the emulsions that tended to form in the exhauster inlet mains.

In discussing catalyst life and effectiveness, the Author did not mean to imply that the results of any chemical or physical tests can necessarily be directly related to catalyst performance. Experience over several years will probably be necessary before the data now being compiled can be interpreted with any degree of reliability. The prolonged and sustained effectiveness of quite heavily-worked batches of catalyst is still causing considerable surprise.

Impingement tests for carbon on the Romford plant have now been replaced by tests employing glass wool as a filtering medium, but both are invaluable as empirical tests that can be performed by shift personnel. More recently, reliable and reproducible results have been obtained by passing a carefully-sampled stream of gas through an "Oxoid" membrane filter paper held in a specially-designed box, and then through a Hyde meter. The sample-tube and filter-box are heated to a temperature above the dew-point of the gas. Owing to the low concentration of carbon in the unpurified gas, such a test must run for about 24 h, before weighable quantities of carbon have been deposited. The problem of carbon detection and measurement is an interesting one, and other types of test are on trial at the moment.

All the contributors to this discussion have been complimentary in their remarks concerning the collection and assessment of data from plant operation at Romford. Two main targets were set, namely :—

(1) To examine and assess the results achieved under various operating conditions and with different types and qualities of feedstock. To elucidate unknown factors and check other conclusions by organizing specially-controlled tests. With all this evidence, to progress in methodical stages of operating technique until optimum conditions could eventually be stipulated for any combination of circumstances.

(2) At each and every stage to ensure that the plant operators knew exactly what was required of them in the way of plant control.

The first of these comes naturally to any qualified engineer or chemist. The second, an exercise in communications, regrettably enough does not, yet it is no less important than the first. What degree of success was achieved in efforts to reach these targets may perhaps be estimated from the results of plant operation that have been quoted in the paper.

* Burns, J., and Stewart, E. R. The Romford Gas Reforming Plant. *Inst. Gas Eng. Comm.* 550.

THE GAS INDUSTRY OF THE U.S.S.R.

By A. P. Agishev

Director of the Ukraine Branch of the All-Union Scientific Research Institute for Natural Gases; Member of the Central Board of the Scientific and Technical Society for the Oil and Gas Industries

Communication No. 590

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I INTRODUCTION

The preparation of this paper was ordered by the Central Board of the Scientific and Technical Society (N.T.O.) for the U.S.S.R. Oil and Gas Industry; its purpose is to acquaint the 98th Annual General Meeting of The Institution of Gas Engineers, of Great Britain, with the basic data illustrating the present state of the gas industry in the Soviet Union, with special reference to the past two years, during which the Soviet people have successfully fulfilled the terms of the Seven-year Plan for developing the economy of our country.

At present, the Voluntary Scientific and Technical Society for the U.S.S.R. Oil and Gas Industry numbers over 48,000 specialists: engineers, technicians, and scientists from the oil and gas industries.

Wherever there are oil or gas industry undertakings, the Society has its basic organizational units, these being the primary organizations and numbering 658. There are such organizations in the gas fields, and at works, gas stations, and institutes, and they are organized territorially under provincial or republican boards. These boards are centralized under the Central Board of the Society. From bottom to top, appointments are made by election.

The central and subsidiary boards have sections covering the various branches of industry: geological and geophysical, oil and gas well drilling, extraction, transportation, storage and refining of oil and gas, production economics, *etc.*

By their activities, the members of the Society working at Soviet Union gas industry undertakings and institutes have made a great contribution to technical progress in the gas industry of our country. In the past two years of the 1959 to 1965 Seven-year Plan, scientific and scientific-technical conferences and meetings have been held to a prescribed plan both centrally in Moscow and on a regional basis in Baku, Kiev, Ufa, Kazan, and other towns; their purpose has been to work out recommendations and proposals for improving methods of prospecting, locating and developing gas fields, on drilling techniques and technology, on operating gas wells, on automation of the working of gas fields and main gas pipelines, and on the refining and utilization of natural and manufactured gas to satisfy domestic and industrial requirements, the latter particularly involving chemical undertakings.

Working on their own initiative, members of our Society have come into contact with certain other similar societies and organizations in making a joint approach to the solving of scientific problems and questions affecting the national economy; instances are the D. I. Mendeleev All-Union Chemical Society, the All-Union Committee on Corrosion, the State Committee on Automation and Machine Construction, *etc.*

Some of the most important meetings held in 1960 were, for example, the All-Union Conference on the Production and Utilization of Compressed Gases, the Joint Plenum of the Central Board of the N.T.O. for the Oil and Gas Industry, and the Board of the D. I. Meedeleev All-Union Chemical Society, the Ukraine Republican Scientific and Technical Conference on the Complex Development of the Ukraine Gas Industry, and other conferences and meetings.

In the autumn of 1958, M. V. Sidorenko, Deputy Head of the Main Administration of the U.S.S.R. Gas Industry, described the state of the gas industry in our country, and the prospects for its development up to 1965, to British gas engineers.

II THE SEVEN-YEAR PLAN AND THE RUSSIAN GAS INDUSTRY

In the past two years, the gas industry of the Soviet Union has been developed as laid down in the directives of the Seven-year Plan for the Development of the U.S.S.R. National Economy between 1959 and 1965. Under this plan, our gas industry is to develop at a vastly accelerated rate. Suffice it to say that the extraction and production of gas is to increase from 29,800 mill. m³ in 1958 to 150,000 mill. m³ in 1965.

The past two years have been years of considerable progress by the comparatively young gas industry in the Soviet Union. This has enabled the fuel balance in our country to be substantially improved: in 1960, the specific demand for gas was 10·3 per cent, i.e., almost double the 1958 figure of 5·5 per cent. It is worth recalling that in 1955 natural gas accounted for only 2·2 per cent in the total fuel balance for the U.S.S.R.

(A) Causes of Progress

What lay behind this vigorous progress by our gas industry?

Firstly, an entirely new approach to the utilization of fuels in our country. The basis of this new approach was the predominant development of extraction and utilization of the cheapest and most efficient types of fuel, oil and gas, while simultaneously reducing the proportion of fuels such as coal, peat, and wood used. The proportion of natural gas used is to increase to 17·5 per cent by 1965. The requirements of natural gas in the Eastern regions of the country and the Urals will show the greatest increase, and in these regions, by 1965, the proportion will be 27 per cent of natural gas. Over the Seven-year Plan, the mean annual increase in the amount of natural gas extracted will be 17,100 mill. m³.

Secondly, our country has colossal resources of mineral fuel, including natural gas. According to the accepted figures, in early 1961 gas reserves in the U.S.S.R. amounted to: recoverable, 2,000,000,000,000 m³; actually prospected, 21·7 trill. m³; total potential, 60 trill. m³.

Thirdly, heavy capital outlay and the adoption of new techniques and production technologies in all the main branches of the gas industry, including such branches as geological prospecting, drilling for gas, extraction and refining of gas, transportation and storage of gas, utilization of gas, construction of main gas pipelines, and scientific research work on gases.

This has stimulated a sudden general upsurge in the gas industry in both the European and Asiatic parts of the U.S.S.R.

(B) Facts and Figures

Let us now give the principal facts and figures illustrating the state of the gas industry in the Soviet Union and the basic trends for development of its principal branches, taking the figures for the first two years of the Seven-year Plan as a basis.

Prospecting for new gas fields over practically the entire territory of our country, from the Carpathians to Kamchatka and from the Caucasus to Ukhta has been continuous in 1959 and 1960. This work has been carried out on the greatest scale in the North Caucasus, Eastern Ukraine, Uzbekistan, Turkmeniya, the Volga Region, Central and Western Siberia, Yakutiya and the Urals.

The extensive work done by Soviet geologists and prospectors has increased the recoverable reserves of gas in the U.S.S.R. by more than 1 trill. m³ during the two years. More than 40 new gas fields have been opened up. This

is the greatest expansion ever achieved since gas prospecting has been carried out in our country.

Three large gas condensate fields, at Serdyukovsk, Ekaterinovsk and Novo-Mikhailovo, were opened up in 1960 in Krasnodar district alone; together with the eight fields already working in this rich gas and oil region, the district has become one of the most important in the U.S.S.R. According to the figures at 1st January, 1961, recoverable reserves amount to 330,000 mill. m³.

Recent geological prospecting has shown that two particular gas fields in the Eastern Ukraine and Uzbekistan contain enormous reserves; these are the Shebelinka and Gazli fields, where the total reserves are estimated at over 1 trill. m³ of natural gas.

In Turkmeniya, large emissions of gas have been sealed at the recently opened Darvaza-Zeaglinsk gas field.

Three gas fields, the Vostochno-Suslovsk, Lugovsk, and Dmitrovsk, have been opened up in the Saratov region on the Volga.

(c) New Prospecting Methods

The ever-increasing part played by new methods of prospecting for gas, which have recently come into use, should be noted. This relates in particular to geophysical methods, including seismological prospecting, deep and spot seismography used widely spaced seismic stations and oscilographic recording, and also the telluric current method, *etc.*

Over the Soviet Union as a whole, quite naturally in recent years, the percentage of wells providing a yield of oil or gas, or providing the required yield, has been satisfactorily high; for example, of 3,779 wells finally drilled and tested in 1959, 2,343 (i.e., 62 per cent) provided a yield and of these 334 provided gas.

An important result of geological prospecting work in 1960 has been that fresh data have been obtained, which confirm the particular importance of Mesozoic deposits to the Soviet Union from the sense of their gas contents. World practice has shown that almost half the entire reserves of oil in the world are contained in deposits of Mesozoic origin.

III METHODS OF RECOVERING NATURAL GAS

To a great extent, the results achieved by opening up new fields has been due to the development of drilling and improvements in techniques and technologies for drilling gas wells. Drilling specially for gas has recently been developed along separate lines. In 1959-60, 2·29 mill. m of gas wells were drilled; this is 15·4 per cent of the total depth of well drilled for oil and gas.

Wells 2,000 m or more deep are drilled with the powerful drilling plant produced by the Ural Heavy Machinery Works; this plant is electrically- or diesel-driven, power plant horsepower being 1,500 to 2,500. For drilling to smaller depths, there are many types of fixed, mobile (on vehicles) and semi-mobile plants of the types produced by the Stalingrad, Baku, and other works.

As in other countries, it has also been found necessary in the Soviet Union, particularly in the case of old gas or oil wells, to change to deep drilling. For instance, in Azerbaijan, close to Baku, vertical wells have already been drilled to a depth of 4,900 to 5,000 m, and wells have been drilled to a depth of 4,300 m at a deflection of 660 m from the vertical.

(a) Turbo-drilling

The main method of drilling is still turbo-drilling, and the wide employment of this method has enabled high drilling rates to be maintained. The adoption of technical improvements in turbo-drill design has also been conducive to this. Experience of drilling in Azerbaijan and other regions has shown that diamond-tipped bits in conjunction with the turbo-drill enable the rate at which deep wells are drilled in hard rock to be considerably increased.

The principal types of turbo-drill at present used are single-, double-, and treble-stage plants, with high turbine-shaft torques. Actual drilling over the last two years has shown that the principal way of increasing turbo-drill efficiency still further is to raise the working pressure of the slush pumps to 200 to 250 atm, and at the same time modifying the drilling plant to some extent.

(b) Electric Drilling

At the same time as turbo-drill efficiency was raised, work was also done on improving the well-bottom electric motors used for electric drilling. Electrically-driven drills with motors of 100, 150 and 230 kW are now in use.

(c) Gaseous Drilling

Gas wells are also being drilled by the method involving blowing with a gaseous agent.

IV THE RUSSIAN FUEL-POWER BALANCE

It is an established fact that manufactured and mixed gases play the principal part in the fuel-power balance in many countries in Western Europe, while natural gases play only a small part. In the Soviet Union, owing to the large number of gas fields in operation, the picture is different. Natural gas, together with gases of oil industry origin (gases obtained when extracting oil, and oil refinery gases) are our most important sources. Gases manufactured from coal and shale are comparatively unimportant.

In 1959, 37·2 milliard m³ of gas were extracted and produced, of which only 1·8 milliard m³ were manufactured.

In 1960, 47·1 milliard m³ of gas were extracted and processed, of which the amount of natural gas and gas produced in drilling for oil was 45·2 milliard m³ (about 96 per cent), and the amount of manufactured gas 1·9 milliard m³ (about 4 per cent). Comparison of the respective figures of 29·8, 37·2 and 47·1 milliard m³ for 1958, 1959 and 1960 respectively thus shows the right rate of annual increase in the total amount of gas extracted and produced.

The gas extracted and produced in 1960 was distributed as follows between Union Republics:—

	Milliard m³	Per cent
R.S.F.S.R.	25·8	55·0
Ukraine S.S.R.	14·3	30·5
Azerbaijan S.S.R. ..	5·8	12·3

The remaining republics in the Soviet Union produced 1·1 milliard m³, or about 2·2 per cent.

Starting with 1961, however, the extraction of natural gas in Uzbekistan will increase greatly, when the Kagansk group of fields is developed and the main Dzharkak-Bukhara-Tashkent gas pipeline is finished.

V THE PLANNING OF UNIFIED PRODUCTION

In connexion with the development of gas fields such as the Gazli, Shebelinka and Severo-Stavropol', in 1960 scientists and specialists in the gas industry concluded the complex work of compiling plans and methods of technological development for these individual gas fields; these plans were to enable the fields to be developed and gas wells to be operated on a scientific basis, with production rigidly planned as a unified whole over the entire area of these huge fields.

For instance, it has been recognized that, in the Shebelinka field in the Ukraine, the many gas strata can be combined in one well by means of a single filter more than 1,000 m long, and this is actually being done; this will enable the number of operational wells to be reduced by several times.

(A) Low-temperature Separation of Hydrates

In the Krasnodar gas fields, where a large amount of condensate is obtained when extracting natural gas, low-temperature separation is being successfully used; by this means, practically dry gas is fed into the main gas pipeline. It must be pointed out that the elimination of hydrates and separation of the condensate are a very urgent problem in most of the gas fields in the Soviet Union, requiring special efforts to provide the final solution.

(B) The Introduction of Automation

Important work has begun on the automation and connexion of gas fields now in operation or being reworked, although in many cases this work is still of a preparatory nature. Of the 1,188 gas wells in operation in the Soviet Union at the beginning of 1960, 148 were converted to partial automation during 1960.

(C) Induced Intensification of Gas Flow

Measures to intensify the flow of gas to the bottoms of wells, including hydraulic fracturing of the gas strata, acid treatment of the formations in gas wells at the well base, torpedoing of the productive part of the stratum, and other measures, have great prospects. In 1959-60, many wells in which hydraulic fracturing was employed showed increased yields.

(D) Increased Labour Productivity

Increase in labour productivity has been particularly high in the gas industry. In 1957, the amount of natural and oil-extraction gas produced per man in the U.S.S.R. was 3·39 mill. m³, while the figure for 1960 was 5·3 mill. m³.

(E) Decreased Cost of Production

Activities in the directions indicated enable us to reckon on the cost of gas production in the gas fields being reduced by several times in the next few years; for example, in 1958 the cost of 1,000 m³ of gas in the Ukraine was 5 roubles 99 kopecks (on the new price scale), while in 1965 it is estimated that the price will have decreased to 44 kopecks. A similar reduction in price is planned for the other gas-extracting regions; Uzbekistan, down to 22 kopecks/1,000 m³; the Volga region down to 23 kopecks, and the Krasnodar district down to 31 kopecks; these figures do not allow for capital outlay on geological exploration. By the end of the Seven-year Plan (by 1965), the net cost of gas extracted in our country will have decreased by about two-thirds.

VI THE DEVELOPMENT OF GAS DISTRIBUTION

1959-60 was a period when new main gas pipelines were being intensively laid. The total length of main pipeline in 1958 was about 12,000 km, while by the beginning of 1961 the length of long-distance pipeline was already 20,000 km.

The more important of the pipelines laid in the last two years are the following: the Serpukhov-Leningrad, Shebelinka-Belgorod-Kursk-Bryansk, the Stavropol'-Groznyi, the Karadag-Tiflis-Erevan, the Dashava-Minsk, the Saratov-Gor'kii, the Dzharkak-Bukhara-Tashkent, the Taganrog-Amvrosievka-Slavyansk, and the Shebelinka-Ostrogozhsk. (See the accompanying map.)

In addition, a second pipe has been laid along the main pipeline from Shebelinka to Dnepropetrovsk; the laying of the new pipeline from Krasnodar district to Moscow, parallel to the previously laid Stavropol'-Moscow pipeline, is continuing. Branch lines have been laid from Taganrog to Zhdanov, and from Dnepropetrovsk to Krivoi Rog; a number of other shorter branch mains, totalling about 800 km, have also been laid.

As a result, we can already call the gas pipeline systems in the Soviet Union extensive, systems developed on the basis of combining existing pipelines and connecting new ones into the system. In the near future, these systems can be interlinked to permit two-way flow, and in many cases large consumers of gas will receive a continuous supply from many directions.

(A) The Gazli-Chelyabinsk-Sverdlovsk Main

The laying of one of the largest main gas pipelines in the world, the Gazli-Chelyabinsk-Sverdlovsk line, began in 1959-60, and this particular line deserves to be described in greater detail.

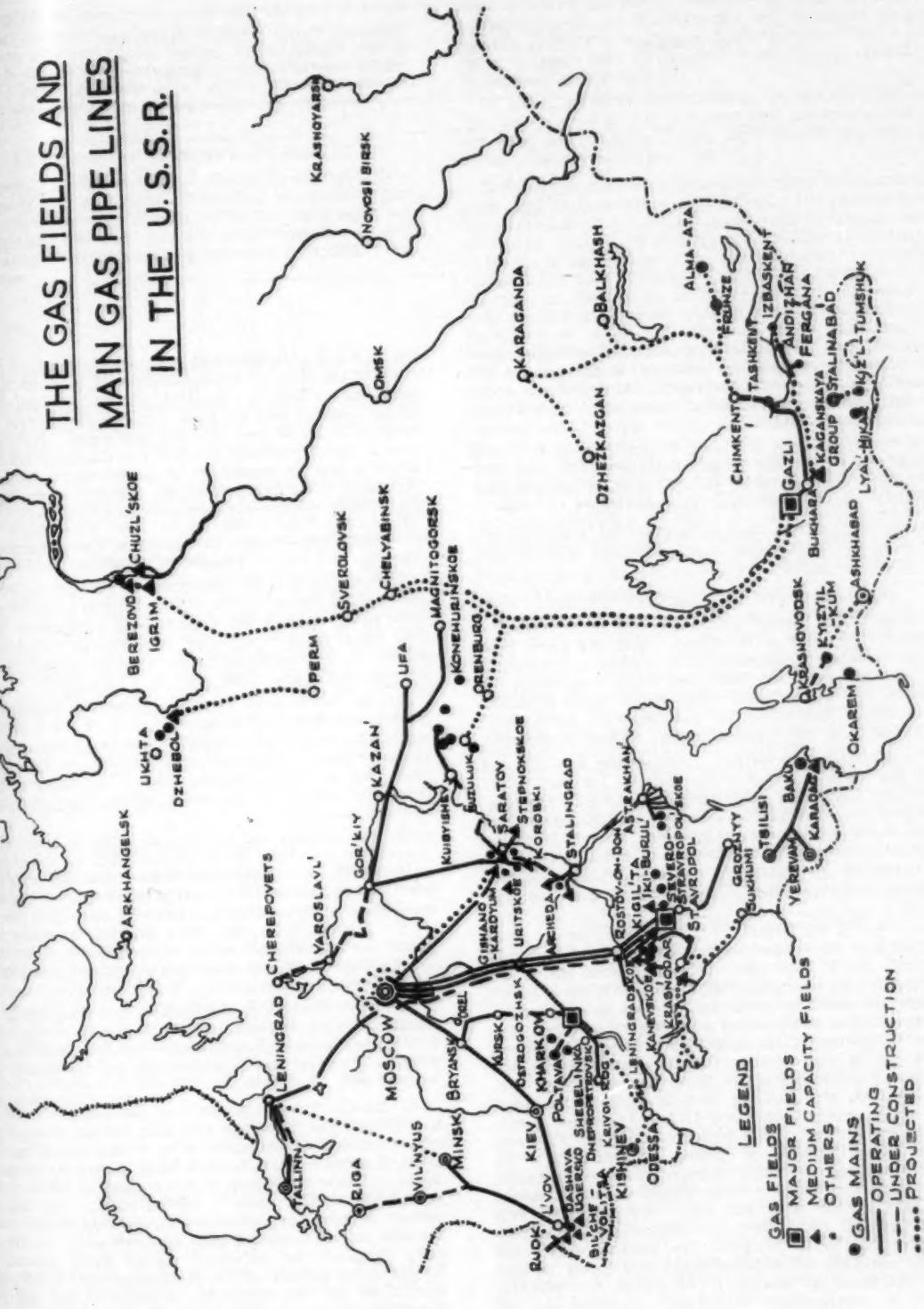
Exploration for natural gas has gone on for a long time in the region of old Bukhara. Only in 1956, however, was the extensive Gazli gas field found in the arid wastes of Kyzyl-Kum; without exaggeration, this gas field can be called the jewel of the Bukhara-Khivinsk Depression. It thus became possible, after laying the pipeline between Dzharkak and Tashkent, to start on the long pipeline from the Bukhara region to the Urals. According to the plan, the line is to consist of two 1,020 mm diameter pipes, the total distance being 1,900 km to Chelyabinsk and 2,200 km to Sverdlovsk. There are many difficulties to be overcome when laying this line; for example, almost 1,000 km of the route lie across waterless desert, in which 1·2 mill. tons of pipe will have to be transported and laid without any roads. There is no doubt, however, that all these difficulties will be overcome, and that the pipeline will be in operation by the planned date.

Economic Advantages of Large-diameter Mains

The question of pipe diameter was deliberated carefully when selecting the parameters for the Gazli-Ural main pipeline. As a result, it was decided to use piping of the largest diameter produced by works in the U.S.S.R. —1,020 mm. Calculations made by the Ukraine State Institute for Design and Planning of Gas Plant (Ukrgiprogaz) confirmed that large-diameter pipes provide the best technical and economic results.

The table at the top of page 6 contains basic figures for capital outlay and operating costs, relating to pipe diameter, per 1 milliard m³ of gas/km.

Calculations and practice have proved that, at the gas pressures of 48 to 64 atm being used, the 1,020 mm diameter pipes are the most economic. The cost of these pipelines is recovered in three to four years, although the


THE GAS FIELDS AND
MAIN GAS PIPE LINES
IN THE U.S.S.R.
KRASNOYARSK
NOVOSIBIRSK
OMSK
KARAGANDA
BALKHASH
DZHEZKAZGAN
ALMA-ATA
FRUNZE
CHIMKENT
TASHKENT
IZBASKENT
ANDIZHAN
FERGANA
KAGANSKAYA GROUP
STALINABAD
LYAL'-NIKAN
TUMSHUK
GAZLI
BUKHARA
ASHKHABAD
KRASNOVODSK
KYNDYL'-KUM
OKAREM
BAKU
KARADAG
YEREVAN
TBILISI
GROZNYY
BUKHUMI
BEREZOVO
CHUZL'SKOE
IGRIM
SVERDLOVSK
CHELYABINSK
MAGNITOGORSK
KONENBURG
ORENBURG
UFA
PERM
UKHTA
DZHEBOL
ARKHANGELSK
CHEREPOVETS
YAROSLAVL'
GOR'KIY
KAZAN'
KUIBYSHEV
BUGULUK
SARATOV
STEPNOKSKOE
KOROBKI
STALINGRAD
ASTRAKHAN'
GIURIANOVO
KARDYMOVO
URITSKOE
ARCHEDA
ROSTOV-ON-DON
KIGIL'TA
IKI-BURUL'
SEVERO-STAVROPOL'SKOE
STAVROPOL
KRASNODAR
KANEVSKOE
LENINGRADSKOE
KOTELNIKOVO
LENINGRAD
MOSCOW
GOMEL'
BRYANSK
KURSK
OSTROGOZHSK
KHARKOV
POLTAVA
KIEV
MINSK
VIL'NYUS
RIGA
TALLINN
LVOV
DASHAVA
UGERSKOE
SHEBELINKA
DNEPROPETROVSKOE
BIL'CHE-VOLOCHAYEVSKOE
KREMENCHUG
KIROVOGRAD
KIRSHINEV
ODESSA
LEGEND
GAS FIELDS
MAJOR FIELDS
MEDIUM CAPACITY FIELDS
OTHERS
GAS MAINS
OPERATING
UNDER CONSTRUCTION
PROJECTED

Pipe Diameter (mm)	Capital Outlay (Thou. roubles/ milliard m³ of gas/km)	Operating Costs (Thou. roubles/ milliard m³ of gas/km)	Metal Used (Tons/ milliard m³ of gas/km)
1	2	3	4
529	27·2	2·3	69·0
720	12·5	1·0	35·0
820	10·4	0·8	30·0
1,020	9·1	0·7	29·8

relative costs of transporting gas are usually higher than the cost of extracting it; for instance, in the case of gas supplied to Moscow from Stavropol', the distance is about 1,300 km and the transportation costs are almost 85 per cent of the total costs.

Over the country as a whole, 40 per cent of the main gas pipelines are of the larger diameters (720, 820, and 1,020 mm). Thus, in 1960, about 2 mill. m³ of gas were transported per km of main pipeline length.

Practice has shown that large-diameter pipelines are more economic both to lay and to operate, although the initial outlay is higher.

(B) Demands of Extremes of Terrain

Pipelines in the Soviet Union are laid in all kinds of conditions: the sands of the torrid desert, the heavy land in the permanently frozen belt, rocky ground, and swamps; work must go on in the boundless forest-steppes, in the mountains, and in the taiga. This makes great demands, not only of the techniques and technology of laying pipelines, but also of the organization as regards manpower.

The organization principally responsible for all this work is the Main Directorate for the Gas Industry under the U.S.S.R. Council of Ministers—the U.S.S.R. Glavgaz. This organization is responsible for all the operations included in the laying of main pipelines, starting from the planning stage and carrying through to handing over the finished pipeline for operation, and the U.S.S.R. Glavgaz in addition operates some of the long-distance pipelines.

(C) Mechanical Aids to Mainlaying

According to the control figures for the first Seven-year Plan, 26,000 km of main gas pipeline are to be laid in the Soviet Union. In 1959 and 1960, about 8,000 km of mains were laid. In order to accelerate the rate at which pipelines are laid, the constructors are now using many new methods: in particular, the continuous laying of pipelines, with the piping laid in the trench after pickling and insulation. Pipeline layers are being better supplied with new excavators, and pickling and insulation machines; high-efficiency rotary excavators, 10 to 20 ton pipe layers, *etc.*, are now in use. The trenchless method of laying pipelines beneath roads at points of intersection by pressing, punching, or forcing through the soil by machine, or by horizontal drilling, is being widely adopted. Aerial photography of the route has been very effectively employed for several years when surveying and planning pipe lines longer than 50 to 100 km. The semi-automatic and automatic methods of welding pipes developed by the Ukraine Academy of Science E. O. Paton Arc Welding Institute in conjunction with the organizations of the U.S.S.R. Glavgaz are now widely used. This has enabled the level of mechanization of work to be greatly increased, as follows: by 95·3 per cent for land work, by 92 per cent for pickling work, by 73·5 per cent for welding work, and by 96 per cent for insulation. Naturally, the rate at which pipelines are laid has increased accordingly. There is now the possibility of increasing the rate at which the mechanized pipeline laying column moves to 1·5 to 2 km/shift (on the basis of a 7-h working day).

(D) Compression of Gas for Long-distance Transportation

For the purpose of long-distance transportation of gas, gas-engined piston compressors of 1,000 to 1,200 h.p. are now being used at the intermediate compressor stations. The initial head is provided, however, by turbo-impellers driven by gas turbines, with a wide range of powers between 4,000 and 9,000 h.p.

At the same time, electrically driven centrifugal impellers are now beginning to be much used in regions where the compressor station is not far from a source of power supply. Although this slightly raises operating costs, this is fully compensated by the benefit obtained from the supply of increased amounts of gas for the national economy.

(E) Automatic Controls

Telemetry and telegraphic signal systems, automation and telemechanization of compressor plants, automatic regulation of compressors, remote control of line cocks on the pipeline route, *etc.*, have enabled the entire system of gas pipeline control to be improved and made cheaper by automation of gas distribution stations, coupled with the necessary maintenance.

Basically, the system of telemetry and telegraphic signal transmission for the purpose of telegraphic control of gas distribution stations, compressor stations, and the long-distance parts of gas pipelines can be considered to be worked out.

At gas-distributing stations in the Ukraine, the input and output gas pressures, and also the gas consumption, are measured telemetrically, information regarding deviations of pressure from normal being passed by telegraphic signal. The entire system of gas-regulating valves is therefore telecontrolled from a switchboard. At the compressor stations, the compressors providing air for starting are also started automatically, and soft water is automatically supplied, the necessary signals being passed. On long-distance sections of the pipeline, as well as telegraphic control of the line cocks, the pressure of the gas in the line traps is measured telemetrically; the rate of flow and

temperature of the gas at the input and delivery sides of the various connexions to gas-distribution and compressor stations are also measured telemetrically, signals being passed to a central despatch-point, where they are reproduced on a mimic bus with digit lighting tubes and equipment for recording them by digit printing machine.

(F) Ejection of Low-pressure Gas

The work that has been done at the Elshano-Kurdyumovsk gas field near Saratov on ejecting low-pressure gas is also worth explaining. The method is that small amounts of high-pressure gas from neighbouring regions are used, thus obviating the necessity for compressor stations to raise the pressure.

VII THE UNDERGROUND STORAGE OF GAS

The development of long-distance gas main circuits with considerable seasonable fluctuations in demand has necessitated the underground storage of gas.

In 1959, the U.S.S.R. Glavgaz inaugurated the first experimental industrial underground storage system; 20 mill. m^3 of gas were forced into water-bearing sands in the Kaluga region. At the same time, industrial experiments were made near Leningrad, aimed at creating underground storage in a horizontal water-bearing stratum. Underground storage of natural gas on an industrial scale (capacity of 55 mill. m^3) has been developed near Saratov. Close to Kuibyshev, as well as four small 15 to 50 mill. m^3 storage pools for natural gas, there are two large storage pools, for gas produced when drilling for oil, of a total capacity of about 1·5 milliard m^3. Underground storage is now being sought in the Ukraine.

Several methods of producing storage pools in rock-salt strata by washing out caverns through well drillings have been developed, and are now being tested, for the storage of compressed gases.

Much effort is being devoted, in the operation of main gas pipelines, to the prevention of corrosion of underground pipelines. The importance of this problem can be gauged if it is considered that, during the Seven-year Plan, almost 10 mill. tons of steel pipe will be laid, the area of contact between gas and pipe being 112 mill. m^2. Two lines are being followed as regards protection of piping from corrosion: (*a*) the application of coatings in the form of bitumens, bitumen-rubber mastics, and coiled "Brizol" material; polyvinyl chloride strip is now being used for this purpose; methods of applying a silicate enamel coating to both sides of piping have been developed, and it is proposed to produce pipe that is insulated at the works; (*b*) electrochemical protection, by means of cathode and protector plant.

VIII GAS SUPPLY

(A) To Industry

The supplying of gas to an ever-increasing number of consumers has involved an expansion in the amount of work associated with the utilization of gas for domestic and industrial purposes. The relationship between the requirements of gas for domestic and industrial purposes arises out of the directives of the Seven-year Plan, according to which "over 80 per cent of all the gas extracted is to be used by industry".

In 1959, industrial undertakings in the U.S.S.R. took 55·4 per cent of all the gas extracted, power stations 29·6 per cent, and communal life requirements together with other consumers 15·0 per cent.

Natural gas is utilized to greatest effect in the metallurgical and cement-kilning industries. The conversion of blast furnaces to gas blast has provided an average saving of 12·4 to 16 per cent of dry coke, and furnace output has at the same time increased by 2 to 4 per cent. Exceptional results have been obtained at particular metalworks: for example, at the Stalino metalworks (in the Donbass), the consumption of coke on melting iron for steelmaking has decreased by about 19·0 per cent, while the furnace ore burden has been increased from 1,700 kg to 2,200 kg/ton of coke, and blast furnace output has increased by 7 per cent. The reduction in the price of a ton of iron has been 2 roubles 90 kopecks (on the new price scale). The total capital outlay at that works was 500,000 roubles, and this was 17 per cent of the value of the coke saved. Industrial experiments carried out in open-hearth furnaces have proved that, in addition to the saving of coke, OH furnace output is definitely increased. In addition, non-oxidizing heating and case-hardening of steel, and the bright annealing of components have become possible at machine-construction works, while the elimination of scaling in forge furnaces reduces losses of steel on combustion and fuel consumption, and lengthens the lives of dies.

A number of large works in the cement-kilning industry have been converted to gas firing, with immediate good results; for example, the output of the rotary kilns at the Belgorod works has increased by 10 to 12 per cent, this providing an additional production of 80,000 to 100,000 tons/annum of cement without any additional expenditure. Gas was first used as a fuel in the Soviet Union cement-producing industry in 1937, when the first rotary kiln working on natural gas came into operation in Baku.

In recent years, the average annual consumption of natural gas on cement kilning has exceeded 2·5 milliard m^3.

(B) To Domestic Consumers

The Soviet Government approaches the problems of gas supply to towns and other populated points from both the economic and the social points of view, since switching over to gas considerably improves the living conditions of the population. Gas supply was laid on to more than 700 towns and villages in 1960, and 28 per cent of all dwelling-space in the country was then supplied with gas. In the Azerbaijan S.S.R. 69 per cent of the housing space is supplied with gas, this being the highest level in the country; this is followed by the Ukraine with 31 per cent and the R.S.F.S.R. with 30 per cent.

In the R.S.F.S.R. alone, over 1,000 km of town gas mains were laid in 1960.

The requirements of compressed gases, which are principally supplied for domestic purposes, amounted to 350,000 tons in 1960, as compared with 100,000 tons in 1958. This was made possible by the organization of a large number of oil-gas works, including works producing reformed gases in regions of Bashkiriya and Tatariya and the towns of Kuibyshev, Baku and Groznyi. Centralized supply of compressed gas in railway tank-cars has been arranged; in 1960, 400 to 420 tons of compressed gas were supplied by rail per tank-car.

IX SCIENTIFIC RESEARCH IN THE RUSSIAN GAS INDUSTRY

In conclusion, let us touch on the problem of the direction that scientific research is taking to ensure technical progress in the U.S.S.R. gas industry.

The principal aim of scientific research work is to improve methods of exploration and prospecting for new gas fields, this being the principal condition for further augmenting reserves of gas. Other angles of research work relate to the sinking of wells so as to ensure that gas fields are rationally worked, both quantitatively and qualitatively; increasing the amount of gas extracted for the minimum capital and operating expenses, automation and telemechanization of gas fields and pipelines, further improvement in the organization and technical handling of the laying of gas pipelines; the construction of compressor stations and oil-gas works, and improvement of technology; the mastery of new methods of forming underground pools for storing natural and compressed gases; and improvement of methods and expansion of the fields in which gas is utilized for industrial purposes and as fuel for the chemical industry.

Great importance is ascribed to the amount of modern technical achievements, which can create a new basis for technical progress in the gas industry of the Soviet Union, which are adopted by industry, and the rate at which they are put into use.

PRESENTATION, DISCUSSION AND REPLY

Presentation

Mr. A. P. Agishev presented his paper as follows:—

In the past two years, the gas industry of the Soviet Union has been developed as laid down in the directives of the Seven-year Plan for the Development of the U.S.S.R. National Economy between 1959 and 1965. Under this plan, our gas industry is to develop at a vastly accelerated rate. Suffice it to say that the extraction and production of gas is to increase from 29,800 mill. m^3 in 1958 to 150,000 mill. m^3 in 1965.

The past two years have been years of considerable progress by the comparatively young gas industry in the Soviet Union. This has enabled the fuel balance in our country to be substantially improved: in 1960, the specific demand for gas was 10·3 per cent, i.e., almost double the 1958 figure. What lay behind this vigorous progress by our gas industry?

Firstly, there was an entirely new approach to the utilization of fuels in our country; secondly, our country has colossal resources of mineral fuel, including natural gas; thirdly, there was heavy capital outlay and the adoption of new techniques and production technologies in all the main branches of the gas industry.

Prospecting for new gas fields has taken place over practically the entire territory of our country, and more than 40 new gas fields have been opened up. This is the greatest expansion ever achieved since gas prospecting has been carried out in our country. To a great extent, the results achieved by opening up new fields has been due to the development of, and improvements in, the drilling of gas wells.

In 1959-60 new main gas pipelines were intensively laid. The total length of main pipeline in 1958 was about 7,500 miles, while by the beginning of 1961 the length of long-distance pipeline was already 12,500 miles. In the near future, the existing pipeline systems can be interlinked to permit two-way flow, and in many cases large consumers of gas will receive a continuous supply from many directions.

Over the country as a whole, 40 per cent of the main gas pipelines are of the larger diameters (720, 820 and 1,020 mm). Practice has shown that large-diameter pipelines are more economic both to lay and to operate, although the initial outlay is higher.

According to the control figures for the first Seven-year Plan, 16,200 miles of main gas pipeline are to be laid in the Soviet Union. In 1959 and 1960, about 5,000 miles of mains were laid. In order to accelerate the rate at which pipelines are laid, the constructors are now using many new methods; in particular, the continuous laying of pipelines, with the piping laid in the trench after pickling and insulation.

The semi-automatic and automatic methods of welding pipes developed in the Ukraine are now widely used. This has enabled the level of mechanization of work to be greatly increased.

For the purpose of long-distance transportation of gas, gas-engined piston compressors of 1,000 to 1,200 h.p. are now being used at the intermediate compressor stations. The initial head is provided, however, by turbo-impellers driven by gas turbines, with a wide range of powers between 4,000 and 9,000 h.p.

The development of long-distance gas main circuits with considerable seasonable fluctuations in demand has necessitated the underground storage of gas.

Several methods of producing storage pools in rock-salt strata by washing out caverns through well drillings have been developed, and are now being tested, for the storage of compressed gases.

The supplying of gas to an ever-increasing number of consumers has involved an expansion in the amount of work associated with the utilization of gas for domestic and industrial purposes. The relationship between the requirements of gas for domestic and industrial purposes arises out of the directives of the Seven-year Plan, according to which "over 80 per cent of all the gas extracted is to be used by industry".

In 1959, industrial undertakings in the U.S.S.R. took 55·4 per cent of all the gas extracted, power stations 29·6 per cent, and communal life requirements together with other consumers 15·0 per cent.

Natural gas is utilized to greatest effect in the metallurgical and cement-kilning industries. The conversion of blast furnaces to gas blast has provided an average saving of 12·4 to 16 per cent of dry coke, and furnace output has at the same time increased by 2 to 4 per cent.

The Soviet Government approaches the problems of gas supply to towns and other populated points from both the economic and the social points of view, since switching over to gas considerably improves the living conditions of the population. Gas supply was laid on to more than 700 towns and villages in 1960, and 28 per cent of all dwelling-space in the country was then supplied with gas. In the Azerbaijan S.S.R., 69 per cent of the housing space is supplied with gas, this being the highest level in the country; this is followed by the Ukraine with 31 per cent, and the R.S.F.S.R. with 30 per cent.

In conclusion, I should like to say that the principal aim of scientific research work is to improve methods of exploration and prospecting for new gas fields, this being the principal condition for further augmenting reserves of gas.

Discussion

Dr. J. Burns, G.M. (London; Deputy-Chairman, North Thames Gas Board):—It is very interesting to contemplate that within the living memory of most gas engineers the gas industry of Britain was based almost entirely on its own indigenous coal. The gas industry of Britain won great credit for the work it did in the carbonization of coal, and it is interesting to see, no matter where one goes in the world, almost invariably carbonization plants that have stemmed from the work of the industry in this country.

Thanks to the coal industry, or perhaps to the "wind of change", the raw material that this industry has had available to it has altered materially during the last decade; we have had to rely on oil and oil products to a very much greater extent. In this, we have sought the help of our international friends and remember with gratitude the assistance given by the American gas industry and the French gas industry, in particular in this matter of the conversion of oil and oil products into town gas.

Now we have a newcomer, the Russian gas industry, and it is very pleasing indeed to think that we are in the forefront of international co-operation with that industry. We look upon it with a certain amount of amazement, for we appreciate that, again within living memory, the fuel industry of Russia was based primarily on coal, peat and wood. In a relatively short time, Russia has sprung to the van in international fuel usage. Indeed, it has more or less gone through the coal age already. It has utilized its coal resources in the meantime to a very marked extent, but with the advent of its tremendous resources of natural gas the emphasis has changed. In this, of course, Russia finds that manpower is a very, very important factor: for example, that the number of men required to produce a unit of energy in the coal industry is very much greater than the number required to produce a unit of energy in the natural gas industry. I do not think that it is in the slightest afraid of the future of the gas industry, based upon natural gas resources, for the Russians will tell you, as Mr. Agishev has done, that so far they have only looked at the resources on the western side of the Urals: the eastern side remains a vast, unexplored area so far as natural gas is concerned.

I find it a little difficult, as, no doubt, do others also, to relate the global figures expressed in milliards of cubic meters as compared with our own better-known millions of cubic feet, but, with the help of the Presidential Address, I came to the conclusion that at present Russia's gas industry is about five times the size of this country's gas industry. That is a great deal of gas to produce in such a relatively short time.

What are the lessons that we could learn from the Russian gas industry? First, we must "take our hats off" to them for the tremendous work that they have done in the transmission of energy, by way of some 16,000 miles of high-pressure pipeline connecting Siberia, Uzbechistan, through the Caspian to the Ukraine to the centres of population and power usage. We note that the Russians are now prepared to put down mains, of some 40 in. diameter, working at pressures of 1,000 lb/in², and begin to realize the tremendous development of gas transmission in that country.

I know that it is not quite fair to compare costs of transmission in view of Russia's vastness and the conditions of land ownership, which are so very different from our own. On the other hand, one cannot fail to recognize the great feats of operation the Russian gas industry has carried out in physically laying these pipelines. One can visualize a pipeline running between Siberia in the north to Uzbechistan in the south, along the line of the Urals, with no break on account of atmospheric conditions, and operated at temperatures as low as −40°F. Our own country, which is very much more contained, is, from the physical point of view, much easier for the laying of gas transmission lines. On the other hand, we may have to contend with greater frigidity from such bodies as, perhaps, the National Farmers' Union, as applied to authorities generally. A great lesson is to be learnt from the Russians in this field of the transmission of energy.

Moreover, Russia transmits energy under the most favourable conditions, in the form of natural gas, to the point of utilization, there to be converted to electricity. We feel that that is the proper way of doing it, for it amounts to bringing one's energy to the point of utilization in the cheapest possible way.

This is a milestone in energy transmission history in The Institution of Gas Engineers, and we are very grateful indeed to have this picture from Russia of what has happened there. We have much to learn. We have before us the possibility of putting down high-pressure pipelines, of 40 in. diameter, operating up to 1,000 lb./in² and requiring minimum utilization of metal. We are very grateful to have been shown how it can be done.

I take this opportunity of thanking Mr. Agishev, on behalf of our colleagues in the International Gas Union, for the very great help that he and his colleagues gave us when we had the opportunity last year of seeing what they were doing in Russia.

Dr. A. E. Haffner (Southampton):—Nearly three years ago Mr. Sidorenko impressed us by his account of the Soviet gas industry*. We learnt more about it during the visit of the International Gas Union last August, and we are grateful for this further review by Mr. Agishev. I was one of the fortunate ones who went to Moscow in August, 1960, but even the information that was presented to us then is already out of date. In the meantime, the maps that we were shown have ceased to represent the real state of affairs. Mains that were shown as being in a state of construction have since been completed. Those that were projected are now under construction; and so it goes on.

The fantastic increases in gas consumption need to be put in rather different terms for their full significance to be appreciated. In 1935, the Soviet gas industry was producing about the same thermal output as the British gas industry, but by 1960 it had become about four times as great, i.e., about the same per head of population. The output by 1965 is predicted to be 24 times that of Great Britain, or six times the consumption per head. The average annual increase alone during the Seven-year Plan will be more than twice the British output. Of course, all this is dominated by the great advantages of availability of abundant reserves of natural gas. This, apart from two minor sources, is not available to us within our shores.

All this remarkable expansion has behind it an epic story of engineering achievement. The oil and gas had to be explored and exploited. The Russians were in a great hurry, and, using existing internationally available techniques as a starting-point, they have added their own improvements in methods of exploration, rapid drilling, pipelining, gas compression, and industrial utilization. Some of the mains are so long that I suspected it had been a chosen economy to lay them along Great Circles, but, on checking, I found that this was not so. The routes were necessary to avoid certain mountain ranges, swamps and deserts.

I was asked, before I went to Moscow in 1960, to ascertain whether that country had a national fuel policy. It has, of course. Indeed, it is so obviously in favour of gas that it must be right! The proportion of the total energy requirement that is contributed by gas is very much greater than that of this country. It is stated that by 1965 the energy available from all sources will total about 1,500 therms, or approximately the usage *per capita* in Great Britain. This index may be regarded as a measure of industrialization, perhaps of civilization, or, indeed, sophistication.

Clearly, gas is getting a high priority in Russia. This is very logical because it takes into account the relatively economical production, cheap transmission and efficient utilization when used directly.

The Author does not say very much about manufactured gas in the U.S.S.R. system, but this still amounts to approximately what is produced by one of our major Area Gas Boards. Obviously, the figure quoted cannot include the gas from the vast coke ovens that are integrated into the steel industry. Does it, perhaps, include underground gasification? I imagine it includes the shale gas of Esthonia, and the Lurgi gas made on the brown coal fields near Tula, south of Moscow. This would account for about a third of the manufactured gas, and I am left with some curiosity concerning the remaining sources of this gas. Have there been any interesting developments in the gasification of coal or oil with oxygen, in fluidization processes, or in catalytic reforming of petroleum feedstocks?

It is a matter of great difficulty to transfer costs from one country to another, but the exercise is rewarding. Does the Author really mean that the cost of producing 1,000 m³ of gas in 1958 in the Ukraine was 599 kopecks, and will fall to 44 kopecks by 1965? This is very much more than the two-thirds decrease mentioned later. Still pursuing the matter of cost of gas to the customer, I was told in Moscow that the Soviet gas is sold to city distribution departments at 1·2 kopecks, and that the customer pays anything from 2 kopecks down to 1, depending on the tariff. The average, therefore, is about 1½ kopecks/m³. Rates of exchange do not help at all in making a comparison, but if it is translated into minutes of work for the Russian worker in buying a therm, as compared with the British worker, one finds that the former would have to work 8 min. for his first therm and 4 min. for later therms as the tariff improved. The British worker would have to work perhaps 20 min. for his first therm, and perhaps 10 min. for later therms. Actually, I am told that domestic gas is often sold unmetered, but charged according to room area and size of family.

Another paper, on the gas industry in the United States and Canada, also refers to the sale of gas unmetered, and depending only on room area*.

* Present-day State and Prospective Development of the Gas Industry in the U.S.S.R. Sidorenko, M. *Inst. Gas Eng. Comm.* 538.

* Some Impressions of the Domestic Use of Gas in the United States and Canada. Eaton, F. J., Wills, D. R., and Fuidge, G.H. *Inst. Gas Eng. Comm.* 592.

Even in these days of space travel, it is a long way from the Ukraine to Kaluga, south of Moscow, where the underground storage system was being developed, but I wonder whether Mr. Agishev could tell us a little more about that system? I ask this question because it is a good opportunity to ascertain information of great interest to this country as it develops the possibilities of its own underground storage systems. It may be that the 20 mill. m³ quoted by the Author refers only to the volume injected in 1959, not the total volume now injected. I had discussions in Moscow with Mr. Alexandrov, and he predicted a much higher level of usage by this date.

The Kaluga system is said to be affected by geological faults, one of which was to be exploited as a convenient closure, and I wonder if the fault has proved to be as effective as may have been hoped. Some of these faults prove treacherous and offer an opportunity for leakage rather than closure. If this system is being currently developed, it would be of great interest to know the injection and withdrawal rates per well.

These figures would help us very much in the design of underground storage systems. We would also like to know more about the experiments going on at Leningrad, and of storage in horizontal aquifers by containing the gases within a ring of artificially created water pressure. Dr. Katz, of Michigan, U.S.A., is doing something very similar, and I am wondering whether there has been any exchange of information and how far progress has been made towards developing storage systems that are not dependent upon one first finding an anticline.

In a country with such extremes of temperature, it was a surprise that the Moscow winter gas demand should be quoted as only 1·3 times that of summer. However, it appears that this is due to the 80 per cent industrial load and interruptible supplies, e.g., to power stations. One heard of stations powered by natural gas in summer and coal in the winter. It may be that the Russians are not content with this method, but are awaiting the chance of developing underground storage systems. It looks as if they are really in earnest about it, for last year some 100 wells were sunk in the search for underground storage possibilities.

I should like to use this opportunity of gaining a little more information, because one or two parts of the paper are still perplexing. What is meant by the telluric current method, mentioned in Section II(c) of the paper, in prospecting for gas? I should also like an explanation of the single filter connecting gas strata and thereby saving the number of operational wells. Does this mean that a single vertical well passing through several gas-bearing strata puts them in communication with each other by perforating the wells in the parts passing through each porous stratum?

In conclusion, I should like to add my thanks to the Author for providing us with the latest information to satisfy our technical interest in the sensational gas engineering achievements and projects to which he has referred.

Mr. D. L. Copp (London):—I found this a most intriguing and interesting paper. We have in this country the highest regard for the technical achievements of Russian pipeliners, and are eager to know more of their materials, equipment and methods.

When I call the paper "intriguing", I mean that the Author has whetted our appetite for information and has stirred up our inquiring minds, but he has left us much upon which to speculate.

Obviously, an extremely powerful pipeline research team has been enrolled, and the gas transmission industry in the U.S.S.R. is greatly profiting thereby. With vast projects of this kind, such a team is absolutely necessary. In the United Kingdom, we are sustaining an international pipeline construction industry of no mean proportions, seemingly without organized national research, and one wonders how. We have, however, a well-established learned society whose sole interest is the study and promotion of pipeline interests. Its first and reigning President happens to be Dr. J. Burns, G.M., one of our own distinguished Past Presidents, who, in fact, opened this discussion. Under his guidance, I am sure that pipelining as a whole is being directed very well indeed, but we do not possess a highly powered research team.

I propose to try to evoke a few answers, sometimes by having my calculations shown to be wrong, or, alternatively, by having none of my presumptions proved right. The questions will be on pure pipelining. Therefore, I skate lightly over Sections I to V of the paper, merely drawing attention to the high proportion of successful drillings achieved, and to the very high drilling mud pressures used.

I have been studying the Gazli-Chelyabinsk-Sverdlovsk twin pipeline project. With 1,020 mm pipes, and, assuming that wall stress is equal to 72 per cent of the yield strength, if X46 steel is used, the pipe walls will be 0·64 in. (16·256 mm) thick. If, as I expect, X52 (or thereabouts) steel is used, the thickness would be 0·57 in. (14·478 mm). In each case, a tolerance of −12½ per cent on plate thickness has been allowed for. Then I assume that the pipes are made of plates 40 ft (say 12 m) long and then double-jointed by machine welding at depôts along the wayleave.

I should like to know how far apart the two lines are spaced, such that disruption of one line would not affect the other.

The Author demonstrates the advantages of large-diameter pipes, and we all remember how clearly this was shown by the series of graphs that Dr. Burns, used in connexion with his Presidential Address to this Institution*.

The welding rates attained in the U.S.S.R. are very high indeed, and welding appears to continue at very low atmospheric temperatures. So far as I know, the only technique to satisfy requirements would be a considerable amount of machine welding. So far as double-jointing is concerned, I presume the technique is submerged-arc using 300 A at 35 V for the first bead, and 400 to 450 A for the capper and one inside run.

What I should like to know is the welding procedure for the "firing-line", i.e., the welds made along the wayleave itself. Is this also by machine, and is there an inside weld? What sort of rate is achieved? Is it not of the order of 50 in. (1·27 m)/min.?

Turning to the finish of the pipe-ends, are they ground down to make a wide "land", followed by jamming the butts tightly together so as to provide a small groove?

The generator necessary to provide current at the suggested rates would be 1,200 A per firing-line, necessitating a 100 h.p. prime mover, a big unit to tow along a pipe track. If this is true, one can imagine the size of the equipment that must be taken along the pipeline route.

I suppose that, with these big welding currents, the pipe ends would be red-hot for a few inches each end by the termination of welding. If so, are they thermally insulated for slow cool-down when air temperatures are below zero?

Mr. Agishev, I gather, is responsible for long-distance gas transmission. He is disturbed at the quantity of gas taken from a long transmission line on account of power for stage pumping. Has anyone thought of placing a liquid products line in parallel with the gas line in the same ditch, the liquid being fuel for the pump prime movers?

According to my calculations, a 4½ in. (115 mm) o.d. pipe carrying gas-oil—a viscous oil would not do—working at maximum pressure of 65 atmospheres and stage-pumped every 100 miles would deliver all the fuel needed, and so the pipeline would deliver all its intake gas.

Lastly, I have been somewhat puzzled by the reference to pickling. Does this involve acid-bath descaling, and phosphate treatment on a transportable basis? I think it does. If so, it is a triumph of engineering to be able to organize this, and I congratulate the Author upon it.

Mr. L. J. Clark, B.E.M. (London):—During the last two and a half years, we have been privileged to hear two papers by eminent engineers from the Soviet Union, telling us of this great story of the development of their resources of natural gas, its transmission and its utilization. Other speakers have given some yardsticks by which to measure the development, but ever since Mr. Sidorenko was here, two years ago, the gas production of the U.S.S.R. has approximately doubled. We know now that the output there is some five or six times that in this country. By 1965, as Dr. Haffner said, it will be more than 20 times that of this country. This is a tremendous achievement and a spur to us all.

To put it in focus, however, we must compare it with the American gas industry, which has been developing over a considerably longer period. At present, its output must be nearly 10 times that of the U.S.S.R., but we do recognize that what has been done in the latter country has involved tremendous technical and engineering skill. Those responsible for fuel policy must have been very quick to recognize the great advantages offered by natural gas, and, throughout their work, there has been complete single-mindedness and purpose. In this country, and others where the gas industry

* *Trans. Inst. Gas Eng.*, 1957-58, **107**, 689.

has developed over a long period, the picture is rather different. We have much plant with several thousands of miles of pipeline, and it may be many years before these projects earn the revenue for which they were designed. At the same time, there are tremendous possibilities for future development in this country. There are many new processes, and many new processes and techniques for gas supply, and there is a risk that valuable time may be lost in discussing and debating the best technique to adopt and the way in which priorities are to be allotted.

Here we may perhaps take some encouragement from the great work done in the U.S.S.R. and re-establish our confidence in the future of the gas industry. We should renew our efforts to develop all the new techniques as fast as possible, establishing them on an economic scale so that they can be fully assessed, technically and commercially. Their further expansion can then be considered in the light of actual experience.

In the field of pipeline development, the U.S.S.R. has been very fortunate that the new techniques for laying have come at a time when their industrial economy is expanding tremendously—particularly where gas and liquid products are concerned. The road and rail systems of that country have probably been developed on a smaller scale than in other countries like our own, and coastwise shipping is not practicable. There is, therefore, no real alternative to the pipeline for conveying these huge amounts of energy. With their single-minded approach, the Russians have been able to press forward with their pipeline schemes, and all concerned have been thinking towards a common purpose. I think this has done much to speed up the work and development.

Reference is made to the problem of removing condensate from the gas at the well-heads, and some work has been done with refrigerating techniques. This process has also been developed in the United States; recently, we had an opportunity of seeing it in practice at one of the large gas fields in the Sahara. For the system to be effective, the gas should be available at the well head at a very high pressure—well over 1,000 lb/in², so that some of the pressure can be dissipated in expanding the gas, thereby creating the necessary refrigerating effect to condense out the heavy hydrocarbons —which would otherwise cause trouble in the transmission lines.

We have also heard of the work done in the development of the compressor stations, and it is understood that intermediate stations along the pipelines are equipped mainly with the traditional type of gas engine-driven reciprocating compressor of 1,000 to 1,200 h.p. Are there many problems associated with the cooling water? One can imagine that, with such machines operating in atmospheric conditions of −40°F, there might be freezing problems.

We learn also that the gas turbine is finding a place in the pumping systems, and large units up to 9,000 h.p. have been installed, particularly for the initial pressure raising and presumably where the gas is available at low pressure. They are simple machines and lend themselves to automatic operation. Further, they require no cooling water. It is interesting to learn that the Russian engineers are hoping to operate some of these plants completely automatically. We should welcome more information on this subject.

Turbo-drilling is referred to, and, although we, as gas engineers, may have had no direct experience of this work, we do recognize that the Russians have been pioneers in this field. Instead of using the long drilling shaft, which may extend down to 3 miles into the ground, they lower the rotary drill and driving air turbine as a unit. Some years ago, the Americans carried out a series of tests with the Russian drills, and found the drilling speeds were very high. They found also that, under American conditions, the cost of operation of the turbo-drills was rather higher than for the traditional shaft drills, because the maintenance and wear and tear were heavier.

The reason for Russian preference for turbo-drills may depend on the urgency with which the gas is required. Perhaps in a rapidly expanding industry, such as that of Russia, one can accept higher drilling costs in the interests of making the gas available in a shorter time. Mr. Agishev has referred to more recent developments and improvements in the turbo-type drills, aimed at reducing costs, and we shall certainly be interested to hear more about these improvements.

Dr. Haffner has referred to some of the work being done in the U.S.S.R. on underground storage, and it does appear that this is still in its early stages of development. I should like to know to what extend our Russian friends are giving priority to this work, for, whereas at present they may be using as much as 80 per cent of their gas for industrial purposes, eventually much of it will be used for space heating. Here the load factor considerations become of greater importance, and the value of underground storage will become paramount.

I congratulate our Russian colleagues on the tremendous progress they have made. It is amazing to consider what effort must be behind the laying of 40 in. pipelines over 1,000 miles long in a year or two. One must first build tube mills capable of producing over 1 mill. tons/a of steel pipe, and the whole system of pipe-laying must be geared to this.

Finally, I should like to express my appreciation of the great hospitality given us in the U.S.S.R. some five or six years ago. They were extremely generous with their technical information and showed us all their new developments.

I recall an occasion when we visited one of the research stations and a methane-liquefaction plant. At about 5 p.m., when the afternoon luncheon was over, we mentioned that we really had not had time to see all of the liquefaction plant, and some features were of particular interest to us. The answer given was: "You may stay as long as you please and we will show you anything you like". They showed us not only their successes, but also the parts of the plant that had caused trouble. No information was withheld. This incident and others like it left us with great hopes for the future of international technical co-operation.

Mr. C. D. Shann (London):—Previous speakers have referred to the technical achievements and tremendous expansion of the gas industry in Russia, and with this I am in full agreement. I should like to draw a comparison with the gas industry of a country that is very much smaller and yet has followed the same pattern of remarkable development over a short period. It is in no sense to detract from the value of the paper to state that it repeats a theme that is now familiar, namely, the revolutionary expansion that occurs in the gas industry of those countries that have been fortunate in discovering and exploiting substantial indigenous sources of natural gas.

Gas engineers in Britain look with admiration to the ways in which their opposite numbers in such countries as the Soviet Union, the North American continent, France, Italy and Pakistan have tackled the problems associated with the very rapid increase in the volume of gas supplied, while our commercial colleagues in the United Kingdom have still to look forward to the day when they can supply gas at a cost that will make its use attractive for electricity generation and for the majority of heating processes in industry, and also as a raw material for the chemical industry.

My particular interest in this paper arises from the fact that I have been fortunate to be associated with the rapid expansion of the gas industry in West Pakistan following the discovery there of natural gas. I do not suggest that there could be any direct comparison between the scale of operations in the Soviet Union and those with which I have been concerned in Pakistan. We talk perhaps in millions where they talk in billions or trillions. Nevertheless, there has been a similar pattern of rapid growth in the demand for this new gaseous fuel, which, we claim with justification is "Clean, convenient, cheap".

This is not the time to describe the gas industry in Pakistan at any length, but it will demonstrate this feature of rapid growth to mention that, although there was no gas industry at all before 1955, the year in which the supply of natural gas from the Sui field commenced, annual production has now reached a figure of around 21,000 mill. ft³ (600 mill. m³). Since the gas has a calorific value close to 1,000 Btu/ft³, this is equivalent to approximately 200 mill. therms/a.

The proven gas reserves in the Sui field are presently estimated at 5,000,000 mill. ft³ (140,000 mill. m³), and the total in West Pakistan at 12,500,000 mill. ft³.

While on the subject of reserves, I should like some explanation of the figures quoted in the paper. In Section II(A), the recoverable reserves are shown as 2 bill. m³, which, although a very impressive quantity, nevertheless appears small in relation to the actually prospected reserves of 21·7 trill. m³, and does not appear to tie-in with the statement in Section II(B), that recoverable reserves have been increased by more than 1 trill. m³ during the two years 1959 and 1960.

I see, in Section V(E), it is reckoned that the cost of gas production will be very considerably reduced in the Soviet Union. I have

been more rash than Dr. Haffner, and have attempted to convert into our own currency the relevant figures. If I am correct, it would appear that in the Ukraine the cost in 1958 was equivalent to 1·63*d.*/therm and that it is anticipated that the cost will be reduced to the remarkably low figure of 0·12*d.*/therm by 1965. It is noted that these costs do not allow for capital outlay on geological exploration, but it would be interesting to know if they do include such ancillary production items as gathering lines and treatment plants? The total production cost at Sui, including exploration, gathering and treatment, is currently 1·35*d.*/therm.

Gas is available for transmission from the Sui field at an initial pressure of 1,100 lb/in² gauge without compression, and the cost of transmission for the system, which includes a pipeline 350 miles in length to Karachi and another 200 miles in length to Multan, is currently 1·8*d.*/therm. This bears out a point made in Section VI(A), that the relative cost of transporting natural gas is usually higher than the cost of extracting it.

The principal uses of gas in Pakistan are for electricity generation, cement-kilning plants, steam raising in textile mills, furnaces in the metallurgical and glass industries, chemical processes, and many other industrial and commercial applications and domestic purposes.

The relationship between the uses of gas may be compared with those quoted in Section VIII as follows:—

Use	*Soviet Union* (per cent)	*Pakistan* (per cent)
Industrial undertakings	55·4	55
Power stations	29·6	40
Communal life requirements and other consumers	15·0	5

Initial development of the gas industry in Pakistan was concentrated on meeting the requirements of industry and electricity generation in order to replace imported fuels by indigenous natural gas, but steady progress is now being made in meeting domestic requirements.

The great majority of the industrial and power station burners were previously fired with imported furnace oil, and in nearly all cases it has been possible to make successful conversions to gas firing. Most of the commercial and domestic appliances used kerosene, or charcoal, and in these cases it has usually been more satisfactory to install new gas appliances.

In the case of one of the cement-kilning plants, the "dry"-process rotary kilns were originally designed to burn coal, were then converted to oil firing, and finally converted to gas firing. This plant has now been operating on gas for five years, but there has been a tendency for output to fall off since conversion, despite a higher heat input in terms of kilocalories per kilogram of clinker produced. As Mr. Agishev states in Section VIII(A), that the output of a rotary kiln at Belgorod increased by 10 to 12 per cent after conversion to gas firing, without any additional expenditure, I should be most interested to learn what fuel was used prior to conversion and also what the kilocalories per kilogram figures were before and after conversion.

I should like to know more about the filter used in the Shebelinka fields. (Section V.) Perhaps it might be possible to include a sketch in the written reply.

What is the effect of welding on the silicate enamel coating? (Section VII.)

Finally, what is the maximum pressure permitted in gas mains in towns? (Section VIII(B).)

Mr. W. T. Hird, M.B.E. (Cardiff):—May I join previous speakers in thanking Mr. Agishev for his most informative and interesting Paper? Mr. Agishev gives us a very clear picture of the tremendous rate of development in the gas industry in the U.S.S.R. This rate of increase is all the more impressive when one realizes, from references to the paper given by Mr. Sidorenko to this Institution at the 24th Autumn Research Meeting in 1958, that the gas industry in the U.S.S.R. is young and only existed at a very low level before 1917. This development has resulted from the finding of very large reserves of natural gas in different parts of the country.

When I read Mr. Agishev's paper, I found references to milliards, billions and trillions in connexion with the volumes of natural gas. The value given to these words is not the same in all countries, and it is not always clear what values are represented. I have had an opportunity to confirm that in this paper milliards and billions refer to 10^9 and that trillions refer to 10^{12}. I should like to suggest that the International Gas Union or the International Organization for Standardization, or both, consider whether international agreement might be obtained on the use of the figure form rather than the word form, since the values would then be clear to all.

To revert to the paper: It is most interesting to see that in 1959 industrial undertakings in the U.S.S.R. took 54·4 per cent of all the gas extracted, power stations 29·6 per cent and communal life requirements, together with other consumers, 15 per cent. This led me to compare the figures with those in the year just ended for the Wales Gas Board, where 34 per cent was sold to industry, 46 per cent to the domestic consumers and 20 per cent to commercial and other users. These comparisons result from many causes, the different age and histories of the gas industries in the two countries, and, becoming of increasing importance in Great Britain, the replacement of solid fuel, traditionally used in open grates, by modern convector gas fires, a type of domestic use not common elsewhere than in Great Britain.

In considering the present trend in Wales in comparison with the figures in Mr. Agishev's paper, it is interesting to note that the total growth in gas demand since vesting date, 1949, is 50 per cent, and that the industrial demand has increased by 154 per cent, the commercial demand by 47 per cent, and the domestic demand by 16 per cent. The average rate of increase over that period was 4 per cent/a, of which the domestic rate of increase was 1 to 1½ per cent. It is of great significance that the rate of increase is currently 6 to 7 per cent, and that the present rate of domestic increase is approximately 4½ per cent/a.

I note particularly from this paper that, in 1959, power stations took 29·6 per cent of the gas extracted. I notice also that electrically driven centrifugal compressors are now beginning to be used in regions where the compressor station is not far from a source of power supply. Mr. Agishev states that, although this slightly raises operating costs, this is fully compensated by the benefit obtained from the supply of increased amounts of gas for the national economy. I should like to ask Mr. Agishev whether the power supplied to these electrically driven compressors is obtained from power stations fired with fuels other than natural gas, and whether the demand for increased amounts of natural gas will, in future years, lead to a decreasing use in power stations. This seems to be a trend in other countries, such as America and France, where natural gas has been widely used in power stations. In this connexion, it is perhaps interesting to quote from an editorial in the April edition of *Pipe Line News*, as follows:—

> "But, with the cost of discovering and producing gas or liquid fuels spiralling ever higher, the curve of economic use of such fuels for power generation has approached, or even crossed, that of the other widely distributed fossil fuel, coal. With coal mining now so highly mechanized that corresponding quantities of heat energy can be produced in coal at the mine for less than in petroleum products at the well, only the problem of transportation, of delivery to strategically (or historically) located power plants, has held back coal's wider use.
>
> "Coal pipelines, their feasibility demonstrated by the performance of one line during 1960, delivering upwards of 1·25 mill. tons of fuel across a span of more than 100 miles, are the next development in energy pipelines. Exploitation of coal-mining areas, many of them located far from present centres of power demand, has been hampered by the inadequacy of wheeled transportation, but may now be expected to offer keen competition to oil and natural gas.
>
> "The next five years, perhaps even a shorter time, will see networks of coal-handling pipelines radiating from the mine areas to gigantic steam power plants constructed adjacent to population centres. In some instances, these coal trunklines will parallel existing natural gas or oil trunks, while in other instances they will cross them to reach such centres as St. Louis or Chicago.
>
> "Pipeline-transported coal, cleaned, pulverized and readied at the mine for most efficient firing, has up to now been handicapped by the requirement of a slurry proportioned around 60 per cent water to 40 per cent coal, with even the most favourable conditions requiring a 50:50 mix. This type of slurry presents two serious problems to the pipeliner and coal user: that of mixture breakdown once the critical velocity for maintaining solids in suspension is lost; and the difficulty

of—or cost of—removing sufficient water to make the fuel readily consumable under boilers.

"Technological development of a slurry with chemical wetting agents, however, now offers the pipeliner a coal 'liquid' with many of the characteristics of a heavy fuel oil. It may be prepared in advance, stored in tanks, and subjected to intermittent pumping without hazard of settling out of the coal either in the tanks or in the line. Coincident with this advance in slurry preparation has come the design of a separator which, in its present stage of development, is capable of drying the slurry to where it consumes readily."

Finally, there are one or two points of technical detail on which I should welcome some information.

Firstly, I should be interested to know how much on the long transmission lines gas is allowed to expand in the length of pipeline between the last recompression station and the point of delivery; the particular interest is, of course, in the maximum velocity of gas flow that is permitted. I should be most grateful if Mr. Agishev could tell us whether any standards for this have been adopted.

Then, I should like to know whether there has been any development in decompression at the end of transmission pipelines by expanding the gas through a turbine to utilize surplus pressure available in the pipelines.

I thank Mr. Agishev once again for an admirably clear and distinguished contribution to the proceedings of the Institution.

Mr. C. P. Henshilwood (London):—In Britain, the gas meter has been described with justice as "the heart of the gas installation". While Mr. Agishev's review is comprehensive, he says nothing about meters. Perhaps this is because they are relatively unimportant in Russia.

It has been the experience of many countries, such as America, the Netherlands and Italy, that, when a change-over from manufactured gas to natural gas is made, the performance of meters can be adversely affected. Where the manufactured gas distributed has a composition such that the oil dressing on the diaphragm of a meter is modified, this subsequent exposure to natural gas can cause drying out of the leather.

This sort of problem is one of interest to the United Kingdom, where the reformation of refinery gas or methane, or the introduction of the Lurgi process, may give a dry gas on the district, which, in turn, may affect meters.

We believe that new meters, or meters that have been exposed to a town gas stripped for benzole will not be harmed by these new gases, but it seems that the history of usage is important and, under some circumstances, the accuracy of registration of meters could change if dry gas were passed through them.

I should be most grateful to Mr. Agishev if he could make available to us any experience in the U.S.S.R. on this problem of the effect on meter performance of a change from manufactured gas to natural gas.

Written Reply

The **Author**, in reply, wrote:—All these matters can be subdivided into several groups relating to different forms of activity, namely: the construction and operation of gas pipelines, the underground storage of gas, economic matters, and certain other groups.

Supplementary information regarding matters that have been raised is given below.

The following are the principal methods used in the U.S.S.R. for welding main pipelines.

Pipelines of 529 to 1,020 mm diameter are arc welded manually, the sections being 36 m long. Special lining-up clamps are used when arc welding butt joints between sections by manual process, the pipe not being rotatable. The first run is deposited using gas-shielding cellulose-covered electrodes. The remaining runs are deposited using electrodes with basic coverings. The sections consist of three 12 m long pipes or six 6 m long pipes. The sections are welded up by automatic submerged arc process at special tube-welding depôts. In this process, the first run is deposited by semi-automatic carbon dioxide process, or manually with gas-shielding cellulose-covered electrodes.

Pipelines of 529 mm or less diameter are resistance-welded, using special mobile plant, or arc welded manually. No backing run is applied from within in any case.

The welding rates are as follows:—Automatic submerged arc 30 m/h, carbon dioxide welding 14 m/h, welding with gas-shielding cellulose-covered electrodes 20 m/h. Resistance-welding output (weld cycle) 2 to 3 min. per butt joint.

When welding in conditions of frost, immediately after welding heat-conserving bands are applied to the welded joints. At air temperatures of −30°C or lower, butt joints must be preheated.

Pipe edges are not pickled before welding. Rust and dirt are removed, using special cleaning machines with safety emery wheels. The metal is cleaned to metallic lustre.

In the case of enamelled pipes, the butt welding does not affect the quality of the enamelling. The only effect is that the enamel in a 4 to 5 mm wide zone immediately adjacent to the weld is fused.

According to the "Rules for Designing and Laying Main Gas Pipelines", when pipelines of 500 mm or more diameter are laid parallel to one another, they must not be less than 9 m apart. At this distance apart, if one pipe bursts it will not affect the other. This distance of 9 m will be used for the Gazli—Chelyabinsk pipeline.

Under the same Rules, it is forbidden to lay pipelines carrying gas and oil products in a common trench, since in this case the bursting of one will damage the other.

Pipelines carrying liquid products and pipelines carrying gas have not been laid simultaneously in the U.S.S.R.

Depending on the diameter of the pipeline, and its delivery, main gas pipelines in the U.S.S.R. are equipped with 1,000 or 1,250 h.p. gas-engined piston compressors, or with turbo-impellers driven by 5,000 h.p. gas turbines or 5,500 h.p. electric motors. At a compression ratio of 1·8, the gas pumped at any of the compressor stations is usually not water-cooled. Whatever the type of equipment, however, there is a standard type of water-cooling system fitted with exhaust fans at each compressor station; in these systems, the oil used for lubricating the compressor plant is water-cooled.

Throughout the seasons, including the cold weather, the cooling system temperature is regulated by switching the fans on and off, and also by connecting or disconnecting individual sections of the tubular spray coolers. No difficulties have been encountered in using water for cooling purposes in this type of system.

Experimental work on testing a mass-produced 300 kW steam turbine as a means of utilizing excess gas pressure at distribution points at large towns have now been concluded. These tests have confirmed the advisability of using gas-expansion machinery at points where excess natural gas expansion energy is available, as substitutes for the standard gas pressure and flow regulators, for producing power and for refrigeration.

Power is supplied to the power networks to which the electrically-driven turbo-impeller stations on main gas pipelines are connected from thermal or hydro-electric stations. The thermal power stations mostly run on pulverized coal, mined by mechanized methods. In the next few years, therefore, the employment of natural gas will not reduce power station capacity. In addition, some of the large thermal power stations located close to main gas pipelines will be converted from solid fuel to natural gas; they will only be supplied with natural gas in the summer, and in winter they will utilize pulverized fuel and a proportion of oil. These thermal power stations will then become compensating users of natural gas, and this will promote maximum loads on the main gas pipelines.

In order to improve labour productivity and reduce the staffs handling the turbo-impellers driven by gas turbines or electric motors on main gas pipelines, a full automation system is now in use for these stations, with prospects for utilizing both local control and remote control from regional and central control-points.

There is no standard rate of flow for gas in main pipelines in the Soviet Union. The rate of flow in main pipelines depends on selecting the ideal parameters for long-distance transportation of gas when designing main gas pipelines, and these parameters are governed by the most economic variant of design. If the design states the diameter of the gas pipe, the rate of flow of the gas can

easily be computed from the gas pipeline delivery equation (the Weymouth, Panhandle and Unigas equations), by dividing pipeline delivery by the cross-sectional area of the piping.

Under the State Gas Technical Inspectorate rules, and depending on the strength of the materials of which the piping is made, in the U.S.S.R. working pressure in main gas pipelines is 56 abs. atmospheres, or 60 abs. atmospheres (principally for commercial gas circuits). The gas pressure at the input side of compressor stations on main pipelines is governed by the ideal compressor plant compression ratio (between 1·3 and 2·5), this ideal ratio being based on technical and economic calculations to select the ideal parameters of further transportation of the gas: the amount of metal used for the piping, the specific power consumption per 1,000 m³ of gas pumped, and the cost of construction per kilometre of pipeline.

The pressures used for town gas mains in the U.S.S.R. are 100 mm w.g. (gas appliances), and 1, 2, 3, 12 and 20 atmospheres. For these pressures, there are corresponding city gas main systems: low-pressure gas supply circuits, medium-pressure gas supply circuits, and high-pressure circuits; between these, there are gas-regulating stations, reducing the gas pressure from high to medium and from medium to low.

Since gas is an extremely cheap form of domestic power for the population of the U.S.S.R., it has been decided to stop installing domestic gas meters in apartments, and to change to a poll tax system. No research whatever is therefore being done in the U.S.S.R. to improve gas meters. Industrial undertakings and power stations utilizing gas as their fuel or raw material principally measure the amount of gas used by means of differential pressure gauges, disc-type flow gauges, or, in rare cases, rotary gas meters similar to the English Connersville meter. The use of domestic gas meters with leather or synthetic-material diaphragms has shown that they work better on natural than on artificial gas, since, when used for manufactured gas, the leather or synthetic materials age more rapidly than in natural gas.

Underground storage, as is known, is being increasingly used in the U.S.S.R. A typical example is the underground storage system in the Kaluga region. In the first three months, 23 mill. m³ of natural gas were injected here, the first such operation, in 1959.

This storage region is now being operated experimentally. The amount already injected is 180 mill. m³, and pumping for research purposes is continuing. When the research is finished and the sealing properties of the stratum above the storage region have been verified, the decision as to whether to construct an industrial plant will be taken. The research plan for the first quarter of 1961 envisaged 1·5 mill. m³/d of gas being taken from storage, the gas being dried at the compressor station. As regards the Leningrad storage experiment, it can be stated that the first results on developing a procedure for calculating the amount of water displaced by gas in gently- and steeply-dipping cupola-shaped water-bearing structures have been successful. Equations have been developed for determining the geological and physical parameters of the stratum as regards distribution of pressure in it when either the flow of liquid or the pressure alters.

A great deal of attention will be paid during the current Seven-year Plan to reducing the cost of extracted and transported gas.

The 66 per cent reduction in the cost of gas over the country, anticipated by 1965, will be achieved by a wide range of measures to improve techniques and technologies of gas extraction, and to eliminate unproductive outlay. It should be stated here that the cost of extracting gas is computed on a basis of including all industrial expenditure on operating wells, this covering miscellaneous industrial circuits, but not including plant for processing gas.

The measures for reducing costs of extracting gas include such items as operating many strata together from one well, for instance in the Shebelinka gas field, where this has made it possible to use a single filter up to 300 to 400 m, or even as much as 600 m, long for the productive part of a well section. For this purpose, the column is lowered already perforated, or is perforated later at points the required distance apart.

The increase in drilling rate due to the improvement of turbo-drilling is also related to a number of factors reducing the cost of gas, since the depreciation of the basic equipment is one of the largest components of production costs. Attention may be drawn here to the new types of turbo-drill, which are cheaper and at the same time more efficient, for example the T12M1-65/8 turbo-drill; this has a plastic turbine and replaceable rubber rings in thrust bearings. This has increased turbo-drill power by 5 per cent and reduced manufacturing costs by 54 roubles per drill (in new prices).

This type of measure includes also the telluric-current method of prospecting for gas, the procedure for which is now well known.

On the basis of the great advantages to be derived from using natural gas in industry and domestically, work on the gasification of coal and other types of raw material is not being expedited in the Soviet Union; consequently, the problems of improvements in this field are not considered urgent at the present stage

Proceedings of Council

The following matters of general interest were among those dealt with by the Council:—

COUNCIL MEETING 11th OCTOBER, 1961

Reports were received of meetings of the following Committees of the Institution :—

(1) COMMITTEE ON UNACCOUNTED-FOR GAS, on 20th July and 7th September, 1961.

(2) GAS WORKS SAFETY RULES COMMITTEE, on 28th July, 1961.

It was agreed to invite the attendance of a representative of The Gas Council Medical Committee to attend meetings of the Gas Works Safety Rules Committee when the agenda contains matters of mutual interest.

(3) GAS WORKS EFFLUENTS COMMITTEE, on 20th September, 1961.

(4) CHAIRMEN'S TECHNICAL COMMITTEE, on 26th September, 1961.

The 22nd Report of the Chairmen's Technical Committee : 1960-61, was approved for publication, and presentation and discussion at the 27th Autumn Research Meeting.

(5) METERS COMMITTEE, on 10th October, 1961.

(6) BOARD OF EXAMINERS, on 26th July, 1961.

(7) GAS EDUCATION COMMITTEE, on 25th July, 1961.

It was reported that Council had given postal approval of the 38th Report of the Gas Education Committee : 1960-61, for publication, and presentation and discussion at the 27th Autumn Research Meeting. The Report would contain the reports of the Board of Examiners and of the Sales Training Committee for the year 1960-61. A recommendation of the Committee, that financial support be given to the holding, under the aegis of the Ministry of Education, of a Short Course for Teachers of Gas Fitting and Gas Technology, in July, 1962, was approved.

(8) CODES OF PRACTICE SUB-COMMITTEE, 17th July, 1961.

An amended revision of the Code of Practice CP 332.201 ("Domestic Hot Water Supply by Gas") (see *Journal*, September, 1961, p. 643) was approved for submission to the Council for Codes of Practice of the British Standards Institution.

A report was received of the Centenary celebrations of the Scottish Association of Gas Managers, which at the conclusion of the celebrations became the Scottish Section of The Institution of Gas Engineers.

Arrangements for the 27th Autumn Research Meeting, to be held on 21st and 22nd November, 1961, at Church House, Westminster, were considered.

A report was made of the meeting of the Council of the International Gas Union, held in Bucharest on 2nd to 6th October, 1961, at which arrangements had been made for the Council to visit an oilfield, a refinery, and a chemical works manufacturing polyvinylchloride by synthesis from methane. The British delegates had also seen a gas-distribution centre and some domestic applications of natural gas.

A report was received of the meeting of the Joint Committee appointed by The Institute of Fuel and The Institution of Gas Engineers to arrange for a Joint Conference on Total Gasification, to be held in September, 1962.

At the Public Works and Municipal Services Congress and Exhibition to be held in November, 1962, the Institution will sponsor a session on the afternoon of Monday, 12th November, when the undermentioned papers will be presented and discussed :—

(1) "New Techniques in the Laying of Gas Mains and Services in Highways, *etc.*, and in Gas Installation Pipes Within Premises", by T. W. Gibson (Croydon) and J. L. Wilson (London).

(2) "Modern Flues and Flues for Modern Buildings", by G. H. Fuidge, B.Sc. (London), and F. J. Eaton, Ph.D., B.Sc. (London).

A report was received of arrangements being made for the Second International Pipes, Pipelines, Pumps and Valves Exhibition and Convention to be held at Earls Court, London, from 9th to 13th April, 1962.

In this Issue...

D. R. Coote

A. P. Agishev

D. R. Coote, B.Sc., 34 years of age, was educated at Eltham College, and King's College, University of London, where he graduated in Chemistry. He joined the Gas Light and Coke Company in 1948, and served with that Company and with the North Thames Gas Board, first as a Pupil Engineer and later as an Assistant Engineer, at various works including Southall, Bow Common, Nine Elms, Bromley and Beckton. Mr. Coote was the youngest member to participate in the first Gas Council Course in Management, at Weybridge, in 1954. In September, 1957, he was appointed Senior Assistant Engineer at Romford Gas Works, where he gained experience in the commissioning and operation of the new catalytic plants converting various hydrocarbon feedstocks into town gas. On 1st May, 1961, he was appointed to the post of Senior Assistant Engineer at Beckton Gas Works.

Aleksandr Petrovich Agishev was born in Uzbekhistan in 1910. In 1932, he left the Moscow Petroleum Institute, having gained the qualification of Mining Engineer through drilling and exploitation of oil and gas deposits. Since 1932, he has worked in the oil and gas industry. He became Chief Engineer, first at the Dal'nevostochno unit, and subsequently at the Sredneaziatsk unit for the extraction of oil and gas. He is now Director of the Ukraine Branch of the All-Union Scientific Research Institute for Natural Gases or "VNIIGAZ". Since 1947, he has taken part in the work of the principal bodies of the Scientific and Technical Society for the Oil and Gas Industries of the U.S.S.R., and at present he is Chairman of the Kharkov Board and a member of the Central Board of that Society.

Examinations: 1962

The Institution of Gas Engineers

Associate Membership Examination

Part I and Part II, Group D, of the Associate Membership Examination will be held on the following dates in 1962 :—

Examination		*Date*
April, 1962	Part I	.. 9th to 12th April.
	Part II ..	.. 3rd to 5th April.

Institution Examination

Part I and Part II, Group B, of the Institution Examination will be held on the following dates in 1962 :—

Examination		*Date*
October, 1962	Part I ..	.. 8th to 11th October.
	Part II ..	.. 2nd to 4th October.

Candidates wishing to enter for the April examination should apply to the Secretary of the Institution, before 8th February, 1962.

Higher Grade Certificates in Gas Engineering (Manufacture) and (Supply)

Although the Higher Grade Examinations in Gas Engineering (Manufacture) and (Supply) have terminated, certain students who have passed these main-subject examinations have been granted permission to complete outstanding ancillary subjects, and applications from students who wish to enter for the 1962 ancillary-subject examinations must be received by the Secretary of the Institution not later than 15th January, 1962.

Principles and Practice of Gas Salesmanship

The Institution of Gas Engineers examination in the Principles and Practice of Gas Salesmanship will be held on Tuesday, 1st May, 1962.

Applications to sit for this examination must be received by the Secretary of the Institution not later than 1st January, 1962.

Candidates who are attending an approved course in the Principles and Practice of Gas Salesmanship, at a technical college, will be entered for the main-subject examination by the college authorities, but they should make sure before the appropriate date, as given above, that the college authorities are aware of their desire to enter.

The Art of Expression

The Institution of Gas Engineers examination in The Art of Expression will be held on Wednesday, 2nd May, 1962.

Applications to sit for this examination must be received by the Secretary of the Institution, not later than 1st January, 1962.

Candidates who are attending a technical college will be entered by the college authorities, but they should make sure before the appropriate date, as given above, that the college authorities are aware of their desire to enter.

City and Guilds of London Institute

The examinations of the City and Guilds of London Institute, in Gas Technology (Manufacture), Gas Utilization and Gas Fitting will be conducted on the following dates in 1962 :—

Gas Technology (*Manufacture*)		
1st Paper ..	Monday, 21st May	6.30 p.m. to 9.30 p.m.
2nd Paper ..	Tuesday, 22nd May	6.30 p.m. to 9.30 p.m.
Gas Utilization (*Intermediate and Final*)		
1st Paper ..	Monday, 21st May	6.30 p.m. to 9.30 p.m.
2nd Paper ..	Tuesday, 22nd May	6.30 p.m. to 9.30 p.m.
Gas Fitting (*Intermediate*)		
Written ..	Tuesday, 8th May	6.30 p.m. to 9.30 p.m.
*Practical ..	Wednesday, 9th May	(6 hours)
Gas Fitting (*Final*)		
Written ..	Tuesday, 8th May	6.30 p.m. to 9.30 p.m.
*Practical ..	Wednesday, 9th May	(8 hours)

*On subsequent days as may be necessary.

Internal candidates for the examinations of the City and Guilds of London Institute in Gas Technology (Manufacture), Gas Utilization and Gas Fitting will be entered for the examinations by the college authorities, but they should ascertain that these authorities are aware, before 24th February, 1962, of their desire to enter.

External candidates for the examination in Gas Technology (Manufacture) (i.e., those unable to attend a course of study at a technical college) should make application to the City and Guilds of London Institute, 76, Portland Place, London, W.1, before 1st February, 1962, to be accepted as external candidates. Such applications should be accompanied by a statement of the circumstances precluding entry as an internal candidate. Candidates so accepted must make their entries before 24th February, 1962, through the local secretary of an examination centre.

Christmas Lecture for Young People

The 11th Christmas Lecture for Young People arranged under the aegis of The Institution of Gas Engineers, will be given by Mr. T. A. Lucas, B.Sc., at the Imperial College of Science and Technology, South Kensington, London, S.W.7, on Tuesday, 2nd January, 1962, at 2.30 p.m. The title of the lecture will be "The Nerves of an Industry".

Admission, which is restricted to young people (13 to 18 years of age), will be by ticket obtainable on application to The Secretary, The Institution of Gas Engineers, 17, Grosvenor Crescent, London, S.W.1, after 1st December, 1961.

News from the Gas Industry Overseas

The full text of articles abstracted below may be consulted in the Library of the Institution.

Activity of Gaz de France in 1960

J. des Industries du Gaz, 1961, August/September, 391-395.

This article and the editorial (p. 361) summarize the Annual Report of Gaz de France for 1960. Compared with 1959, the sales of gas have increased by 8 per cent for domestic use, 7·7 per cent for commercial and 12·2 per cent for industrial use, an overall average of 8·9 per cent. Coal used has dropped from 3·6 mill. tonnes to 3·14 mill. tonnes. Gas purchased has increased by 39 per cent, the quantity of natural gas purchased having trebled since 1959. The proportion of coal gas distributed has fallen from 75 per cent to 63 per cent. Sales of coke, at 1·97 mill. tonnes, have increased by 10 per cent; the actual production did not increase, but stocks have fallen. Distribution mains have been extended by 1,700 km, and 170,000 new dwellings have been connected to the supply, making a total of about 5·82 mill. consumers. Forty-six gas works have been shut down. Natural gas, either as such or after reforming, represents 27 per cent of the total gas supply. The production from Lacq has risen to 20 mill. m³/d, or, after purification and treatment, 13·5 mill. m³/d of gas for sale. The progress of research investigations is recorded, notably in regard to the liquefaction of methane and the transport and storage of liquid methane. Reference is also made to investigations on the laying of a submarine pipeline from Algeria to Europe. Finally, the article surveys the activities of Gaz de France in the field of education and training, and the prospects of the industry for 1961.

New C.G.A. Building Reflects Gas Industry Growth

Canadian Gas J., 1961, August, 19-21.

The Canadian Gas Association was born 54 years ago, when 12 men, representing the gas industry, recognized the need of forming themselves into an organization that could speak with a corporate voice. For many years, the offices of the Association were in the home of the Secretary. Because of the rapid growth of the natural gas industry, the headquarters have moved four times in the past 10 years, and recently the Association has purchased and moved into completely new permanent headquarters in suburban Toronto. For the first time since the Association commenced its approvals programme five years ago, testing laboratories are located in the same building as the Approvals Division. The facilities include, *inter alia*, equipment for testing everything from a 25 lb furnace-conversion burner to a 15 ton industrial heating boiler. Special work booths are available where manufacturers can prepare equipment for testing and make minor modifications. The Association's membership now numbers 644, and the number of its active committees has grown to 65. The staff, under the Managing Director (William H. Dalton) comprises 45 persons, of whom 25 are full-time employees of the Approvals Division. The library is a special feature of the new headquarters.

Dusts and Fogs in Town Gas: Their Detection and Composition

L. Creusot. *J. des Industries du Gaz*, 1961, August/September, 373-383.

A gas stream may carry in suspension droplets of saline solutions (the principal cation being ammonium), spherelets of oils, gums and divers particles such as iron oxide (rust, purifying ore, *etc.*), iron sulphide, carbon black, alumina, nickel, Prussian blue, *etc.* The author, after defining these different types of particle and discussing their origin, describes the methods adopted for their detection in a gas stream involving (*a*) their recovery from the stream, and (*b*) the behaviour of a small flame of the gas in question. Apparatus for the collection of the particles from low-pressure and medium-pressure streams are described, with drawings. Graphs are also drawn, showing the relation between time and flame height of the test burners. The particles collected are characterized according to their appearances, state of free surface, colour, dimensions and nature. In an appendix are given fuller operational details of the methods used at the test points and for the examination of the deposited particles.

Pre-reforming of High-C.V. Gases

H. W. J. Kempen. *Het Gas*, 1961, 1st September, 145-147.

The term " pre-reforming " is used to denote the dehydrogenation and cracking of the higher hydrocarbons in refinery gas. The author reports (with drawings) experiments made, in the Ibing plant at the municipal gas works at The Hague, for the production of pre-reformed gas. The process does not require the addition of steam. In the early trials, considerable amounts of tar and naphthalene were formed. By subsequent modification of the reaction vessel, tar formation was eliminated and naphthalene formation was reduced. The yield from 1 m³ refinery gas was 1·2 m³ pre-reformed gas, typical analyses, before and after, being:—

	Refinery Gas (Per Cent)	Pre-reformed Gas (Per Cent)
CO_2	0	1
C_2H_4	10	16
C_2H_6	2	0
CO	2	3
H_2	15	25
CH_4	38	40
C_3H_6	21	6
C_3H_8	3	0
N_2	9	9
Calorific Value (kcal/m³) ..	9660	7560
Specific Gravity	0.72	0.60
Delbourg Index	58	68

Successful Surveys Bring Closer World's First Sub-sea Gas Line

M. Moyal. *Gas Age*, 1961, 14th September, 31-35, 70.

Commercial exploitation of the great Hassi R'Mel gas deposits should yield some 700 bill. ft³/a for 50 years. Of this, Algeria herself can use little more than 10 per cent. France already has her ample Lacq deposits, so that the main outlet for the new gas must be to Britain, Western Germany and other European countries. The gas may be transported in liquefied-methane tankers or by submarine pipeline. For the latter, three alternative routes are possible, (i) across the Strait of Gibraltar, involving a crossing of 18 miles, at a depth of about 1,500 ft, (ii) through Sicily and Italy, and (iii) from Mostaganem (Algeria) to Carthagena (Spain), involving 114 miles at depths down to 8,850 ft. The author describes the experimental work conducted by Gaz de France on the technique of pipelaying at these depths, and on the picking-up of the pipe for maintenance or repair. A special steel, known as X95, has been produced, having adequate ductility, strength and stress resistance to withstand external pressures as high as about 4,300 lb/in², and internal pressures of 5,600 lb/in². The experimental pipe used is of 8 in. diameter with a wall thickness of 0·435 in. The surveys have shown that:

(*a*) the pipe can be lined up readily along the submarine route and will remain satisfactorily on the bottom;

(*b*) the offshore pipelaying techniques evolved are workable and the values taken as bases for calculating buoyancy, pressure, tensile strength, *etc.*, as well as the movements of the pipe when dropping into water are correct;

(*c*) in the event of sudden storm, the section could easily be dropped onto the sea bed and later picked up again.

Gaz de France is making further surveys and plans to make a start on actual construction of the pipeline by 1964 or 1965.

Versatile Barrel Furnace Line Improves Steel Bar Production

R. E. Buckholdt. *Amer. Gas J.*, 1961, September, 24-28.

The author describes, with illustrations, a 2,000 lb/h gas-fired, barrel-type, continuous heat treating furnace installation

for annealing stainless steel bars, which are generally hexagonal, square or round and range in thickness from $\frac{1}{2}$ in. to $4\frac{1}{2}$ in. The equipment, which is unusually compact, comprises five separate heating units and an annular quench ring, making a heating machine 20 ft long and 5 ft wide. Run-in and run-out tables are each 25 ft long. This line treats as much as a direct-fired continuous furnace of conventional design that is 120 ft long by 12 ft wide. One man operates the entire barrel furnace line. A mixture of natural gas and air is burned in ceramic-lined, cup-shaped burners. The ceramic lining becomes radiant, speeding combustion of the fuel mixture and providing for transfer of a major part of the heat by radiation. There is no flame impingement on the workpiece. The bar is heated in an atmosphere of neutral combustion products, the short exposure in this atmosphere preventing scale formation. The average fuel consumption is about 38,000 ft³/24 h of 1,000 Btu gas. Bar size and length changes require no adjustment except centring the quench ring, and only minor changes are needed to change from annealing stainless to normalizing regular alloy bars.

Personal Notes

Appointments

(*a*) *By Area Gas Boards:*

EAST MIDLANDS GAS BOARD

Notts. and Derby. Division—

Chesterfield District—

District Distribution Engineer : **R. L. Carter.**

Assistant Distribution Engineer : **D. E. Loverseed.**

WEST MIDLANDS GAS BOARD

Chief Distribution and Installations Engineer : **F. Bell, B.Sc.**

(*b*) *General:*

Mr. K. A. Deadman, B.Sc. (AM), has recently taken up an appointment as an Assistant Lecturer in Chemistry at the County Technical College, Wednesbury.

Mr. S. R. Kay (AM), has recently taken up an appointment as an Engineer in the Projects Group of the Engineering Department of Imperial Chemical Industries, Limited, Heavy Organic Chemical Department.

Mr. D. W. McClellan (AM), is now Distribution Engineer of Colonial Gas Holdings, Limited, Footscray, Australia.

Addresses Required

The Council would be grateful to receive the present addresses of the following members, last heard of in the places given in brackets :

Mr. W. G. Bignell (Eastbourne).
Mr. D. J. Bradley (London).
Mr. E. Clark (Bridlington).
Mr. S. W. Hayes (Braunton).
Mr. D. Helliwell (Halifax).
Mr. P. W. Hugh (Middlesbrough).
Mr. C. Kay (Cambridge).
Mr. N. P. Shepherd (London).
Mr. A. W. Somerville (Bury).
Mr. A. M. Steel (Gutersloh, Germany).
Mr. L. H. Watson (Coventry).
Lt.-Col. T. C. Whimster (Ashford).

Meetings of Affiliated Associations

Scottish Western Junior Gas Association

The opening meeting of the new session took place on Friday 1st September, 1961, within the Industrial Section, 9, George Square, Glasgow. Mr. A. J. Blackie (President, 1960-61) installed Mr. A. M. Jackson, Dumbarton, into office for the session 1961-62.

Mr. Jackson introduced Mr. D. Beavis, President, The Scottish Association of Gas Managers, who spoke to the meeting on the forthcoming formation of a Scottish District Section of The Institution of Gas Engineers, and the relationship with the Scottish Juniors.

Mr. Jackson then read his Presidential Address, which was entitled " Prepare for Success " and dealt with such themes as communications, management, and education. At the conclusion, there was a lively discussion.

The meeting ended with the presentation of The Society of British Gas Industries' Silver Medal to Mr. G. B. Scott, Glasgow, and of the Association Short Paper Prize to Mr. R. L. Bissett, Dumbarton.

Scottish Combined Junior Gas Associations

Some 100 members of both the Scottish Eastern and Western Associations visited the Lurgi Plant at Westfield, Fife, on 9th September, 1961. The tour of the gasification and ancillary plant commenced at 11 a.m., and groups were formed and conducted by members of the Westfield staff.

At 12.30 p.m., there was a break for luncheon at which Mr. T. S. Ricketts, Chief Engineer, The Scottish Gas Board, spoke to the guests about some of the stages of planning and construction leading up to the official opening of the plant by Her Majesty The Queen in June this year.

The afternoon session permitted those present to see every stage in the Westfield Lurgi process.

The President of the Scottish Western Junior Gas Association (Mr. A. M. Jackson) thanked The Scottish Gas Board for the opportunity of visiting the Lurgi plant. He thanked also Mr. Ricketts, Mr. Eggins and the staff at Westfield for the organization of the visit and the hospitality provided.

Forthcoming Meetings

The following meetings have been arranged for the six weeks commencing 1st November, 1961:

(*a*) District Sections

THE INSTITUTION OF GAS ENGINEERS—EASTERN SECTION

6th December	Joint Meeting with the Eastern Junior Gas Association. Paper, "The Background of Industrial Relations in the Gas Industry", by A. B. Badger, M.A., Ph.D. (The Institution of Gas Engineers, 17, Grosvenor Crescent, London, S.W.1.)

THE INSTITUTION OF GAS ENGINEERS—LONDON AND SOUTHERN SECTION

28th November	Paper, "The Use of Instruments in the Production and Distribution of Gas", by J. R. Kenward and T. A. Lucas. 2.45 p.m. The Caxton Hall, Caxton Street, London, S.W.1.)

THE INSTITUTION OF GAS ENGINEERS—MANCHESTER AND DISTRICT SECTION

10th November	Ordinary General Meeting. Paper, "Natural Gas at Whitby", by F. C. Barker. (George Hotel, Huddersfield.)

THE INSTITUTION OF GAS ENGINEERS—NORTH OF ENGLAND SECTION

2nd November	Paper "Remote Instrumentation on Tyneside", by J. E. Peacock. (2.30 p.m. The Distribution Centre, Northern Gas Board, Market Street, Newcastle-upon-Tyne.)
7th December	Joint Meeting with the Northern Junior Gas Association. Showing of The Scottish Gas Board's film of the crossing of the River Forth with introduction and commentary by R. C. Emmony. (2.30 p.m. The Lecture Room, News Theatre, Newcastle-upon-Tyne.)

THE INSTITUTION OF GAS ENGINEERS—SOUTH WESTERN SECTION

6th December	Paper, "A Technical Exercise in Functional Interdependence", by Dr. M. J. F. Olden and P. G. Jackson. (Gloucester.)

(*b*) Junior Gas Associations

EASTERN

14th November	Short Paper Competition. (Peterborough.)
6th December	Joint Meeting with the Eastern Section, The Institution of Gas Engineers. Paper, "The Background of Industrial Relations in the Gas Industry", by A. B. Badger, M.A., Ph.D. (The Institution of Gas Engineers, 17, Grosvenor Crescent, London, S.W.1.)

LONDON AND SOUTHERN

3rd November	Annual Reception and Dance. (Caxton Hall, Caxton Street, London, S.W.1.)
10th November	Paper, "Maintenance of Gas Works Electrical Equipment", by W. Shaw. (6.30 p.m. Westminster Technical College, Vincent Square, London, S.W.1.)
16th November	Visit to Thomas Potterton, Limited, Warwick.
1st December	Paper, "The Safe Operation of Mechanical Handling Plant", by R. W. Cutts. (6.30 p.m. Westminster Technical College, Vincent Square, London, S.W.1.)
14th December	Visit to J. Lyons and Company, Limited, Cadby Hall, London, W.14.
15th December	Paper, "Retrospect on American Visit", by S. B. Scott. (6.30 p.m. Westminster Technical College, Vincent Square, London, S.W.1.)

MANCHESTER

25th November	Visit to Cammell Lairds, Birkenhead. Paper, "Experiences with Installing Warm-air Heating in Existing Houses", by F. Eames.
9th December	Short Papers for F. Johnston Prize. (Manchester Industrial Development centre.)

MIDLAND

21st November	Paper, "Gas Governor Developments", by R. Hutchinson. (West Midlands Gas Board, Staff Mess Room, Council House, Birmingham.)
12th December	Short Paper Evening. (West Midlands Gas Board, Staff Mess Room, Council House, Birmingham.)

NORTHERN

23rd November	Visit to the Sunderland Works of the Northern Gas Board. (2.30 p.m.)
7th December	Joint Meeting with the North of England Section, The Institution of Gas Engineers. (Newcastle.)

SCOTTISH (WESTERN)

3rd November	Paper, "Corrosion", by J. S. Hogg. (6.30 p.m. Scottish Gas Board, 9, George Square, Glasgow.)
9th December	Joint Meeting with the East of Scotland Junior Gas Association. (3 p.m. Albany Street Social Club, Edinburgh.)

WALES AND MONMOUTHSHIRE

8th November	Short-paper Meeting. (Pontypool.)
5th December	Visit to Grangetown Gas Works of the Wales Gas Board. Paper, "Recent Developments at Cardiff", by J. B. Currier. (Cardiff.)

WESTERN

15th November	Paper, "Central Heating by Gas—Design Considerations", by E. I. Luscombe. (Bristol.)
13th December	Paper, "Central Heating by Gas—Design Considerations", by E. I. Luscombe. (Plymouth.)

(*c*) Kindred Bodies

Members of The Institution of Gas Engineers who wish to attend any of these meetings, but are not members of the bodies concerned, should apply to the appropriate Secretary at the address indicated.

THE CHEMICAL SOCIETY

(Burlington House, London, W.1.)

14th November	Centenary Lecture. "Some Reactions of Free Radicals", by Prof. G. B. Kistiakowski. (6.30 p.m. Room F1, Manchester College of Science and Technology, Manchester.)
14th November	Paper, "Experimental Methods in the Study of Chemical Kinetics", by Prof. J. C. Robb, Ph.D. (5 p.m. The Department of Chemistry ,The University, Nottingham.)
16th November	Centenary Lecture. "Some Reactions of Free Radicals", by Prof. G. B. Kistiakowski. (7.30 p.m. The Rooms of the Society, Burlington House, London, W.1.)
16th November	Joint Meeting with the Students' Union Chemical Society of the Royal Technical College, Salford. "The Biogenesis of Alkaloids", by Sir Robert Robinson, O.M., D.Sc., F.R.S. (5 p.m. The Conference Hall, Royal Technical College, Salford.)
17th November	Joint Meeting with the University Chemical Society. Official Meeting and Centenary Lecture. "Some Reactions of Free Radicals", by Prof. G. B. Kistiakowski. (8.30 p.m. The University Chemical Laboratory, Cambridge.)
30th November	Paper, "Aspects of the Biosynthesis of Phenolic Compounds", by Prof. C. H. Hassall. (6.30 p.m. The Chemistry Lecture Theatre, The University, Leeds.)
5th December	Paper, "Some Recent Observations on the Activity of Metal Catalysts", by Prof. C. Kemball. (4.30 p.m. The University, Leicester.)
8th December	Joint Meeting with the Royal Institute of Chemistry, the Society of Chemical Industry and the Society for Analytical Chemistry. Paper, "The Structure of Natural Products by Direct X-Ray Analysis", by Prof. J. Monteath Robertson. (7.15 p.m. The Royal College of Science and Technology, Glasgow.)
14th December	Liversidge Lecture. "Stereospecific Polymerization", by Prof. C. E. H. Bawn, C.B.E. (7.30 p.m. The Lecture Theatre, The Royal Institution, Albemarle Street, London, W.1.)

THE COKE OVEN MANAGERS' ASSOCIATION (SOUTHERN SECTION).

(Honorary Secretary, Southern Section: J. A. Clarke, Esq., 51, Gwern Rhuddi Road, Cyncoed, Cardiff.)

17th November	Paper, "Factors Affecting the Choice of Conveyor Belting", by R. K. Routledge and C. B. Bullough. (6.45 p.m. Park Hotel, Cardiff.)

THE INSTITUTE OF FUEL

(18, Devonshire Street, Portland Place, London, W.1.)

2nd November	Paper, "Refractories", by H. M. Richardson. (6.30 p.m. Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham, 2.)
8th November	Paper, "Coventry Water-treatment Process", by I. Aitken. (6.30 p.m. The Engineers' Club, Albert Square, Manchester. 2.)
8th November	Joint Meeting with Liverpool Engineering Society. Paper, "Gas in Industry on Merseyside", by H. C. Elles. (7 p.m. Liverpool Engineering Society's Rooms, 9, The Temple, 24, Dale Street, Liverpool, 3.)
5th December	Paper, "Recent Developments in the Heating of Domestic Premises", by P. T. Loader. (6.30 p.m. The Gas Showrooms' Lecture Theatre, Nottingham.)
7th December	Paper, "Developments at Garston Works", by W. S. Hubbard. (7 p.m. Liverpool Engineering Society's Rooms, 9, The Temple, 24, Dale Street, Liverpool, 3.)
7th December	Paper, "The Benson Boiler", by W. P. C. Ungoed. (6.30 p.m. Birmingham Exchange and Engineering Centre Stephenson Place, Birmingham, 2.)
13th December	Joint meeting with the National Society for Clean Air. Paper, "Shell Boiler Developments", by G. Gunn. (6.30 p.m. The Engineer's Club, Albert Square, Manchester, 2.)

THE INSTITUTION OF ELECTRICAL ENGINEERS

(Savoy Place, London, W.C.2.)

6th November	Paper, "The General Problems of F.M. Multi-channel Communications", by R. G. Medhurst. (5.30 p.m. Savoy Place, London, W.C.2.)
14th November	Paper, "Tracking in Insulation", by N. Parkman. (5.30 p.m. Savoy Place, London, W.C.2.)

16th November — Paper, "The Design and Performance of High- and Low-voltage Terminal Boxes", by K. K. Schwarz. (5.30 p.m. Savoy Place, London, W.C.2.)

20th November — Discussion on "Electrical Accidents and their Causes, including the Legal Aspects". To be opened by S. J. Emerson, O.B.E. (5.30 p.m. Savoy Place, London, W.C.2.)

21st November — Discussion on "The Precision Required in the Calibration of Industrial Instruments". To be opened by P. M. Clifford and A. Felton. (5.30 p.m. Savoy Place, London, W.C.2.)

23rd November — Discussion on "The 57 Effects of an Electrical Current". To be opened by G. S. Brosan. (6 p.m. Savoy Place, London, W.C.2.)

29th November — Paper, "Recent Developments in Semiconductor Devices and their Applications", by E. Wolfendale. (5.30 p.m. Savoy Place, London, W.C.2.)

THE INSTITUTION OF ENGINEERS-IN-CHARGE

(Honorary Secretary: A. T. Penn, Esq., 13, Grange Close, Edgware, Middlesex.)

14th November — Paper, "The Contribution of Nuclear Reactors to Engineering Progress", by K. T. Wooton. (6.30 p.m. Magnet House, Kingsway, London, W.C.2.)

13th December — Paper, "The Hot Dip Galvanizing Process", by M. H. Davies. (6.30 p.m. Caxton Hall, Caxton Street, London, S.W.1.)

THE INSTITUTION OF HEATING AND VENTILATING ENGINEERS

(49, Cadogan Square, London, S.W.1.)

1st November — Paper, "Basic Principles of Control Application with Explanation of a Complex Job Breakdown", by D. H. Powell and C. W. Spangle. (6 p.m. The Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1.)

1st November — Paper, "Warm-air Door Curtains", by J. N. Saunders. (6.30 p.m. The College of Technology, Leicester.)

3rd November — Paper, "Warm-air Door Curtains", by J. N. Saunders. (6.30 p.m. The Engineers' Club, Albert Square, Manchester, 2.)

7th November — Paper, "Background to the Industry", by B. A. Hodges. (6.30 p.m. The Institute of Mining and Mechanical Engineers, Neville Street, Newcastle-upon-Tyne.)

7th November — Paper, "Anthracite Fuels for Domestic and Industrial Boilers", by S. R. Crook. (6.30 p.m. The G.E.C. Building, Cardiff.)

14th November — Paper, "Structural Insulation of Buildings", by J. Lawrie. (6.30 p.m. The Engineering Centre, Stephenson Place, Birmingham.)

20th November — Paper, "The Importance of the Heating Engineer to the Architect", to be given by an eminent Merseyside architect. (6.30 p.m. The Exchange Hotel, Tithebarn Street, Liverpool.)

21st November — Paper, "The Heating and Ventilating of Coventry Cathedral", by A. F. Myers. (7 p.m. 25, Charlotte Square, Edinburgh.)

28th November — Informal Debate. "This House considers that domestic heating installations should be carried out by qualified heating engineers and not by other professions or trades". Motion proposed by K. W. Dale. Motion opposed by R. G. Sayers. (6.30 p.m. The Junior Institution of Engineers, Pepys House, 14, Rochester Row, London, S.W.1.)

5th December — Paper, "Experience in America of Heating and Air Conditioning Practice", by C. S. K. Benham, O.B.E. (6.30 p.m. The Institute of Mining and Mechanical Engineers, Neville Street, Newcastle-upon-Tyne.)

6th December — Paper, "Some Aspects of the Work of the Heating and Ventilating Research Association", by N. S. Billington. (6.30 p.m. The College of Art and Crafts, Waverley Street, Nottingham.)

8th December — Paper, "Some Important Aspects of Oil-firing as Applied to Sectional and Shell Boilers", by N. Charlesworth. (6.30 p.m. The Engineers' Club, Albert Square, Manchester, 2.)

12th December — Paper, "Fans: Types and Uses", by J. W. Stammers. (6.30 p.m. The Engineering Centre, Stephenson Place, Birmingham.)

14th December — Paper, "Fire Protection in Buildings", by E. A. Hibbitt, M.B.E. (6 p.m. The Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1.)

THE INSTITUTION OF MECHANICAL ENGINEERS

(1, Birdcage Walk, London, S.W.1.)

2nd November — Process Engineering, Refrigeration, Ventilation and Vacuum Plant Group Discussion of Problems of Maintenance in the Petroleum and Kindred Industries. (6 p.m. 1, Birdcage Walk, London, S.W.1.)

22nd November — James Clayton Lecture. "Reflections on the Institution's Rôle in Engineering Education", by Prof. E. Giffen. (6 p.m. 1, Birdcage Walk, London, S.W.1.)

29th and 30th November — Conference on Oil Hydraulic Power Transmission and Control. (10.45 a.m. 1, Birdcage Walk, London, S.W.1.)

6th December — Paper, "Lubrication Oil Filter Testing", by K. E. Buckman and S. W. Kemp. Paper, "A Standard Contaminant for Oil Filter Testing", by A. T. Weare. (6 p.m. 1, Birdcage Walk, London, S.W.1.)

THE INSTITUTION OF PLANT ENGINEERS
(2, Grosvenor Gardens, London, S.W.1.)

1st November	Paper, "Development of Oil-cooled Rotary Portable Compressors", by P. C. Bevis. (7.30 p.m. Grand Hotel, Leicester.)
7th November	Paper, "Pilot-scale Research Work at the D.S.I.R. Warren Spring Laboratory", by S. H. Clarke, O.B.E. (7 p.m. The Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2.)
7th November	Paper, "Application of Modern Industrial Switch and Control Gear", by P. C. Belton. (7.30 p.m. White Lion Hotel, Church Street, Peterborough.)
8th November	Paper, "Organization of Planned Maintenance", by H. Bamford-Preston. (7.15 p.m. Grand Hotel, Broad Street, Bristol.)
9th November	Joint Meeting with The Institution of Heating and Ventilating Engineers. Paper, "Industrial Air Conditioning, with particular reference to Car Body Paint and Spray Plant", by V. C. Taylor. (7.15 p.m. The Scottish Building Centre, 425, Sauchiehall Street, Glasgow, C.2.)
9th November	Paper, "Automatic Boiler Control for Medium- and Small-size Boilers". (7 p.m. Roadway House, Oxford Street, Newcastle-upon-Tyne, 1.)
11th November	Paper, "Gas in Industry", by A. Mackechnie. (7.30 p.m. 25, Charlotte Square, Edinburgh.)
14th November	Paper, "High-pressure Hot Water Systems", by A. E. Lock. (7.15 p.m. Manchester Literary and Philosophical Society's Rooms, George Street, Manchester.)
15th November	Paper, "Coal Utilization", by D. Hicks. (7 p.m. The Sherwood Room, County Hotel, Theatre Square, Nottingham.)
15th November	Paper, "Hydraulic Control Systems", by J. C. Wells. (7 p.m. The Railway Hotel, Dartford.)
23rd November	Paper, "Refractories for Boilers and Furnaces—Construction and Maintenance", by M. Ash and N. W. Hinchcliffe. (7.15 p.m. The Blossoms Hotel, Chester.)
23rd November	Paper, "Design and Installation of Gas and Chemical Plant". (7 p.m. Stockton-on-Tees.)
23rd November	Paper, "Standards and the Plant Engineer", by H. Stafford. (7.30 p.m. Sheffield.)
27th November	Paper, "Basic Electronics in Industry and Commerce", by R. H. Garner. (7.30 p.m. The Houldsworth School of Applied Science, The University, Leeds.)
28th November	Paper, "Design for Maintenance", by R. N. Dale. (7 p.m. The Electricity Showrooms, 62, Kingsway, Swansea.)

THE INSTITUTION OF STRUCTURAL ENGINEERS
(11, Upper Belgrave Street, London, S.W.1.)

14th November	Joint Meeting with the Manchester Society of Architects. Paper, "Architectural Misconceptions of Engineering", by A. J. Harris. (6.30 p.m. The College of Science and Technology, Manchester.)
20th November	Paper, "Economics of Framed Structures", by L. R. Creasy. (6.30 p.m. New Civil Engineering Building, The University, Brownlow Hill, Liverpool.)
23rd November	Paper, "Services and Air Conditioning for Tall Buildings", by J. R. Kell. (6 p.m. Meeting Hall, 11, Upper Belgrave Street, London, S.W.1.)
28th November	Joint Meeting with the Edinburgh and East of Scotland Association of The Institution of Civil Engineers. Paper, "Piling", by W. G. N. Geddes. (6 p.m. Heriot-Watt College, Edinburgh.)
29th November	Paper, "Air Conditioning and Services for Tall Buildings", by J. R. Kell. (6.30 p.m. Royal Victoria Hotel, Sheffield.)
1st December	Paper, "Instability of Thin-walled Members", by P. S. Bulson. (6.30 p.m. Main Lecture Theatre, Lanchester Building, The University, Southampton.)
5th December	Paper, "Crane Erection Problems", by W. H. Arch. (7 p.m. The Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow.)
6th December	Paper, "The Plastic Design of Steel-framed Structures", by Prof. M. R. Horne. (6.30 p.m. The College of Science and Technology, Manchester.)
6th December	Paper, "Some New Developments and Applications of Prestressed Concrete", by H. Kaylor. (6.30 p.m. The Neville Hall, Newcastle-upon-Tyne.)
14th December	Paper, "The Chemical and Physical Effects of Aggressive Substances on Concrete", by P. E. Halstead. (6 p.m. Meeting Hall, 11, Upper Belgrave Street, London, S.W.1.)

THE PIPELINE INDUSTRIES GUILD
(7, Iddesleigh House, Caxton Street, London, S.W.1.)

14th November	Paper, "The Thames/Lee Tunnel", by F. Tattersal. (6.30 p.m. Tudor Room, Caxton Hall, Caxton Street, London, S.W.1.)
12th December	Paper, "Measurement of Flow in Pipelines", by Dr. F. A. L. Winternitz. (6.30 p.m. Tudor Room, Caxton Hall, Caxton Street, London, S.W.1.)

THE ROYAL INSTITUTE OF CHEMISTRY
(Honorary Secretary, London Section: G. C. Ackroyd, Esq., B.Sc., Fire Offices' Committee, 107, Cheapside, London, E.C.2.)

2nd November	Joint Meeting with the Brunel College of Technology Chemical Society. Paper, "Modern Developments in Co-ordination Chemistry", by J.

	Lewis. (7 p.m. The Brunel College of Technology, Woodlands Road, London, W.3.)
6th November	Joint Meeting with the Woolwich Polytechnic Scientific Society. Paper, "Ion-exchange Resins", by Prof. C. W. Davies. (7.30 p.m. Woolwich Polytechnic, Thomas Street, London, S.E.18).
30th November	Joint Meeting with the Battersea College of Technology Chemical Society. Paper, "Chemical Aspects of the Works of the Warren Spring Laboratory", by C. C. Hall. (7 p.m. Battersea College of Technology, Battersea Park Road, London, S.W.11.)

SOCIETY OF CHEMICAL INDUSTRY

(14, Belgrave Square, London, S.W.1.)

1st November	Paper, "The Industrial Water and Effluents Group", by Dr. B. A. Southgate. (6.45 p.m. The Royal Institution, Albemarle Street, London, W.1.)
3rd November	Jubilee Memorial Lecture. "The Organization of Research and Development", by Dr. F. Roffey. (7.15 p.m. The Royal College of Science and Technology, Glasgow.)
6th November	Paper, "The U.K.A.E.A. and its Relations with Industry", by Dr. N. Goodway. (6.30 p.m. 14, Belgrave Square, London, S.W.1.)
7th November	Paper, "Super Refractories in the Chemical Industry", by M. O. Parker. (7.30 p.m. Lea Park Rooms, Falkirk.)
8th November	Joint Meeting with the Chemical Society and the Royal Institute of Chemistry. Paper, "Some Principles and Practices in Corrosion Protection", by Dr. T. P. Hoar. (7.30 p.m. Heriot-Watt College, Chambers Street, Edinburgh, 1.)
15th November	Jubilee Memorial Lecture. "The Organization of Research and Development", by Dr. F. Roffey. (7 p.m. University College, Cathays Park, Cardiff.)
15th November	Discussion on points of doubt and dispute in corrosion science. (6 p.m. 14, Belgrave Square, London, S.W.1.)
16th November	Paper, "The Chemical Industry's Approach to Process and Plant Design", by Prof. J. M. Coulson. (6.30 p.m. Stephenson Building, King's College, Newcastle-upon-Tyne.)
24th November	Joint Meeting with the North Wales Section of the Royal Institute of Chemistry. Paper, "Oxygen—Gaseous and Liquid: Its Production and Growth", by J. B. Smith. (7.30 p.m. Denbighshire Technical College, Wrexham.)
8th December	Paper, "The Structure of Natural Products by Direct X-ray Analysis", by Prof. J. Monteath Robertson. (7.15 p.m. The Royal College of Science and Technology, Glasgow.)
12th December	Paper, "Production of Low-sulphur Aromatics", by G. Claxton. (6 p.m. 14, Belgrave Square, London, S.W.1.)
14th December	Special Meeting on New Test Methods. "The Use of a Density Column in a Storage-stability Test for Tar/Bitumen Mixtures", by Dr. E. D. Tingle, N. Wright and M. Stewart. "The Examination of Preserved Timber by Gas—Liquid Chromatography", by Dr. D. McNeil. "The Immersion Wheel-tracking Test", by D. H. Matthews. "Pipeline Enamels: Laboratory and Field Methods of Test", by G. McHardy. "A Test for Ease of Spreading of Bituminous Mixtures for Roads", by A. Please and R. Hardman. (2.30 p.m. 14, Belgrave Square, London, S.W.1.)

THE SOCIETY OF INSTRUMENT TECHNOLOGY

(20, Queen Anne Street, London, W.1.)

15th November	Paper, "Instrumentation at Low Temperatures", by Dr. R. G. Chambers. (7.30 p.m. Department of Physics, The University, The Royal Fort, Bristol.)
29th November	Paper, "Differential Producers for Flow Measurement", by H. E. Dall. (6.45 p.m. Welsh College of Advanced Technology, Cathays Park, Cardiff.)
4th December	Paper, "Problems of Flow Measurement", by H. E. Farrer. (7 p.m. Department of Fuel Technology, The University, Mappin Street, Sheffield.)
7th December	Paper, "Electronic Controllers", by A. H. Isaac. (7.30 p.m. The Cleveland Scientific and Technical Institution, Middlesbrough.)
12th December	Paper, "Design Application and Selection of Automatic Control Valves", by P. Stone. (7 p.m. Stanley Palace, Watergate Street, Chester.)

Glossary of Terms Used in the Gas Industry

The British Standards Institution has now re-issued as B.S. 1179:1961 the revised " Glossary of Terms Used in the Gas Industry ", first published in 1944 at the request of The Institution of Gas Engineers. The present revision has been prepared under the authority of the Gas Industry Standards Committee, and incorporates new terms and modified definitions that have been adopted in the intervening period.

The glossary deals primarily with those technical terms special to the gas industry and as far as possible its scope is limited to such terms as have a definite and important significance in the industry. Excluded from the glossary are subsidiary descriptive terms and those which, though commonly used by gas engineers, have the same meaning in the industry as in their ordinary usage. The exceptions relate to those cases where the use of such terms might be ambiguous. Terms that might be regarded as colloquial, or words predominantly local in use have in general been avoided. Two extra sections dealing with terms relating to raw materials and refractories, now appear in the revised glossary. Specialized terms relating to particular types of gas-burning appliances and their fittings are excluded wherever possible, on the grounds that the gas industry codes of practice, issued separately since the first edition of the glossary, deal adequately with them.

Where different branches of the gas industry use similar terms, but with somewhat different meanings, appropriate definitions are given in corresponding sections of the glossary. In those cases where different designs for the same type of plant or apparatus exist, definitions are general enough to cover all such variations.

Terms are arranged in order of increasing specialization in each of the 13 sections of the glossary, which are classified as follows :—General. Raw Materials. Carbonization. Gasification. Refractories. Gas Purification. Products. Storage. Compression. Governing. Distribution. Utilization. Measurement.

Definitions which it is considered should be used preferentially are typographically differentiated from those less favoured and from those that it is hoped will fall into disuse.

For convenience of reference, each definition has been assigned a number divided into three specified groups.

Whilst it is hoped that the form of all the definitions is such as to allow for changes in design and technique, it is accepted that British Standards should be reviewed periodically to keep abreast of modern developments. Suggestions for the improvement of the glossary will be welcomed, and considered in the course of any future revision.

B.S. 1179:1961 (" Glossary of Terms Used in the Gas Industry ") is obtainable, price 20*s.* (net) a copy, direct from the British Standards Institution, 2, Park Street, London, W.1.

Library Accessions

The following are a few additions to the Library since the issue of the *Journal*, Vol. 1, No. 10, October, 1961:

British Standard 131: Part 1: 1961 (Methods for Notched Bar Tests, Part 1: The Izod Impact Test on Metals).

British Standard 412: 1961 (Specification for Fittings for Cylinder Pressure Indicators for Reciprocating Engines).

British Standard 845: 1961 (Code for Acceptance Tests for Industrial-type Boilers and Steam Generators).

British Standard 871: 1961 (Specification for Abrasive Papers and Cloths for General Purposes).

British Standard 1123 : 1961 (Specification for Safety Valves, Gauges and Other Safety Fittings for Air Receivers and Compressed-air Installations).

British Standard 1179 : 1961 (Glossary of Terms Used in the Gas Industry).

British Standard 3338: Part 10: 1961 (Methods for the Sampling and Analysis of Tin and Tin Alloys, Part 10: Iron (Photometric Method)).

British Standard 3407 : 1961 (Test Code for Coke-screening Plant).

Commonwealth Scientific and Industrial Research Organization (Australia) 13th Annual Report, 1960-61.

1961 Directory of Canadian Gas Utilities. (Canadian Gas Association.)

Electricity Council Annual Report and Accounts, 1960-61.

Electronic Computers. Principles and Applications, by T. E. Ivall. 2nd ed. (Iliffe; 1960.)

Final Report of The Trade Effluents Sub-Committee of the Central Advisory Water Committee. (Ministry of Housing and Local Government; 1960.)

High-speed Computing. Methods and Applications, by S. H. Hollingdale. (English Universities Press; 1960.)

Portable Fire-extinguishing Appliances. (Fire Protection Association; 1961.)

Public Health Act, 1961: Ch.64.

Pugging and Extrusion Research 1958-1959. *Brit. Ceramic Res. Assoc. Special Publication No.* 28, 1961.

Rivers (Prevention of Pollution) Act, 1961: Ch.50.

Simple Approach to Electronic Computers, by E. H. W. Hersee. (Blackie; 1960.)

Year-book of The Coke Oven Managers' Association, 1961.

General Notices

99th Annual General Meeting: 1962

The 99th Annual General Meeting of The Institution of Gas Engineers is to be held from 15th to 18th May, 1962. The business sessions will be held in the Central Hall, Westminster.

International Dictionary of the Gas Industry

The International Dictionary of the Gas Industry, initiated by the International Gas Union, was published earlier this year and full details were given in a brochure enclosed in the June issue of the *Journal*.

Copies have been despatched by the printers to those members who took advantage of the reduced subscription then offered. Further copies are available to members of the Institution at a reduction of about 15 per cent of the published price of £6. In order to obtain this discount, orders must be placed through the International Gas Union and be accompanied by a remittance of 52·5 Dutch florins, which includes packing and postage.

The Secretary of the Institution will, on request, be pleased to supply an order form for this purpose.

The Houldsworth Society

The annual departmental and Society dinner of the Houldsworth School of Applied Science, University of Leeds, will be held at the Guildford Hotel, Leeds, on 17th November, 1961.

Tickets and further details may be obtained on application being made to the Secretary, The Houldsworth Society, The University, Leeds.

Conference on Oil Hydraulic Power Transmission and Control

The Institution of Mechanical Engineers Hydraulic Plant and Machinery Group is to hold a Conference on "Oil Hydraulic Power Transmission and Control" in the Institution's Main Meeting Hall, on 29th and 30th November, 1961.

Arrangements have been made for the presentation of some 20 authoritative papers, with opportunities for discussion not only in the conference hall, but at informal social gatherings. Additionally, manufacturers of hydraulic equipment have kindly agreed to admit visitors to their works.

A registration form to attend this conference is available on application to The Secretary, The Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, S.W.1.

Binding of the *Journal*

Arrangements have been made for binding annual volumes of the *Journal* to members' order. The December, 1961, issue will contain an index to the volume for 1961 and an order form, which readers will be able to send to the binders along with their copies of the 12 monthly issues and a remittance of £1 8*s*. The binders will remove the paper covers and advertising matter from each issue and will bind the remaining text into a blue buckram cover similar in appearance to those formerly used on the bound volumes of the *Transactions* of The Institution of Gas Engineers. This cover will be embossed in gold with the crest of the Institution and an appropriate title. A title page will also be inserted in the bound copy.

The binding will be undertaken by Straker Brothers, Limited, who are also the printers of the *Journal*. For readers who wish to make their own arrangements for binding the *Journal*, it will be possible to obtain the embossed binding cases separately from Straker Brothers, at 8*s*. each.

Consideration is being given to an alternative arrangement for subsequent volumes of the *Journal*, whereby members could reserve, *in advance*, each year, a bound copy of the *Journal* which would be additional to their monthly issues (which would be posted as usual). The material for this bound volume would be laid aside by the printer each month, thereby assuring its preservation in good condition, and would be bound immediately after the December issue had appeared. Members would thus receive, at the end of 1962, a bound copy in perfect condition, and their monthly issues would still be continuously available. They would also be saved the trouble of posting copies back to the printer for binding at the end of the year. It is estimated that the cost of a bound volume prepared in this way would be £1 13*s*., but *it must be emphasized that this service would be available only to subscribers to the monthly issues, and bound copies will not be sold separately*. This second method would require firm orders for the additional bound volumes to be placed at the beginning of each year, and it is requested that readers who contemplate adopting this procedure for 1962 should write *now* to the Secretary, The Institution of Gas Engineers, 17, Grosvenor Crescent, London, S.W.1. If it appears that sufficient demand exists for this service, arrangements will be made with the printers.

Readers who wish to have their own copies bound at the end of the year, need take no action until they receive the December, 1961, issue of the *Journal*, which will contain an order form and full instructions.

International Factory Equipment Exhibition

A complimentary ticket is included in this issue of the *Journal*, for admission to the International Factory Equipment Exhibition to be held at Earls Court, London, from 13th to 18th November, 1961.

Library

The Library and Reading Room of the Institution are open on weekdays between 9 a.m. and 5.30 p.m. Members may borrow books by post, excepting books of reference and certain others, on application to the Secretary.

Benevolent Fund

Contributions to the Benevolent Fund of the Institution may be paid at any time to the Secretary of the Benevolent Fund, 17, Grosvenor Crescent, London, S.W.1. It is a convenience if annual contributions are made by banker's order, and it is particularly advantageous to the Fund if such contributions are made by Deed of Covenant, whereby the Fund is able to reclaim from the Inland Revenue an appropriate sum in respect of income tax paid by the contributor. Further particulars, with deed forms and banker's orders for completion, are obtainable from the Secretary of the Fund.

Officers of District Sections and Affiliated Associations

Sections

Eastern

Chairman :	K. B. Meggitt, M.I.Gas E., Eastern Gas Board, Gas Works, Ford End Road, Bedford.
Honorary Secretary and Treasurer :	J. Hunter-Rioch, M.B.E., M.I.Mech.E., M.I.Gas E., Eastern Gas Board, 52, Sidney Street, Cambridge.

London and Southern

Chairman :	R. M. Farror, M.I.Gas E., South Eastern Gas Board, Katharine Street, Croydon.
Honorary Secretary and Treasurer :	J. T. Veryard, B.Sc., M.I.Gas E., South Eastern Gas Board, Katharine Street, Croydon.

Manchester and District

Chairman :	N. C. Sturrock, M.I.Gas E., North Eastern Gas Board, 48, James Street, Harrogate.
Honorary Secretary :	J. Castle, B.Sc., M.I.Gas E., North Western Gas Board, Radiant House, Bold Street, Liverpool, 1.
Honorary Treasurer :	A. Harrison, M.I.Gas E., 297, Bramhall Lane South, Bramhall, Cheshire.

Midland

Chairman :	F. Harvey, M.I.Gas E., West Midlands Gas Board, Tame Bridge, West Bromwich Road, Walsall.
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Chairman :	K. E. Brown, A.M.I.Gas E., Northern Gas Board, Market Street, Newcastle-upon-Tyne.
Honorary Secretary :	W. Cummings, A.M.I.Gas E., Northern Gas Board, 30, Grainger Street, Newcastle-upon-Tyne.
Honorary Treasurer :	A. Field, M.I.Gas E., Northern Gas Board, 19 King Street, Penrith, Cumberland.

Scottish

Chairman :	D. L. Dickson, M.I.Gas E., Scottish Gas Board, Gas Offices, Cumberland Street, Dumfries.
Honorary Secretary and Treasurer :	W. Kirk, M.I.Gas E., Kessington, 29, Union Street, Greenock.

South Western

Chairman :	T. W. Jackson, M.I.Gas E., South Western Gas Board, 9a, Quiet Street, Bath.
Honorary Secretary :	F. C. Gay, M.B.E., F.C.I.S., Assoc.I.Gas E., Radiant House, G.P.O. Box No. 141, Bristol, 1.
Honorary Treasurer :	T. A. Nicholson, A.M.I.Gas E., South Western Gas Board, 34, Bridge Street, Taunton.

Wales and Monmouthshire

Chairman :	S. L. Wright, B.Sc., M.I.Gas E., Wales Gas Board, Grangetown Gas Works, Cardiff.
Honorary Secretary :	J. Powdrill, M.B.E., A.M.I.Gas E., Wales Gas Board, Bute Terrace, Cardiff.
Honorary Treasurer :	O. P. Cronshaw, M.B.E., M.I.Gas E., Wales Gas Board, 93, Wellington Road, Rhyl, N. Wales.

Affiliated Associations

Irish Gas Association

President :	W. A. Campbell, M.I.Gas E., Belfast Corporation Gas Works, Ormeau Road, Belfast.
Director :	N. J. Robertson, Assoc.I.Gas E., Alliance and Dublin Consumers' Gas Company, Dublin, Eire.

British Junior Gas Associations' Joint Council

Chairman :	T. W. Pickthall, A.M.I.Gas E., North Western Gas Board, Stanley Buildings, Silver Street, Bury.
Honorary Secretary :	L. G. Townsend, M.Sc., M.I.Gas E., North Western Gas Board, Hind Street, Birkenhead, Cheshire.

Officers of District Sections and Affiliated Associations

Sections

Eastern

Chairman :	K. B. Meggitt, M.I.Gas E., Eastern Gas Board, Gas Works, Ford End Road, Bedford.
Honorary Secretary and Treasurer :	J. Hunter-Rioch, M.B.E., M.I.Mech.E., M.I.Gas E., Eastern Gas Board, 52, Sidney Street, Cambridge.

London and Southern

Chairman :	R. M. Farror, M.I.Gas E., South Eastern Gas Board, Katharine Street, Croydon.
Honorary Secretary and Treasurer :	J. T. Veryard, B.Sc., M.I.Gas E., South Eastern Gas Board, Katharine Street, Croydon.

Manchester and District

Chairman :	N. C. Sturrock, M.I.Gas E., North Eastern Gas Board, 48, James Street, Harrogate.
Honorary Secretary :	J. Castle, B.Sc., M.I.Gas E., North Western Gas Board, Radiant House, Bold Street, Liverpool, 1.
Honorary Treasurer :	A. Harrison, M.I.Gas E., 297, Bramhall Lane South, Bramhall, Cheshire.

Midland

Chairman :	F. Harvey, M.I.Gas E., West Midlands Gas Board, Tame Bridge, West Bromwich Road, Walsall.
Honorary Secretary :	D. K. Green, M.I.Gas E., West Midlands Gas Board, Foleshill Road, Coventry.
Honorary Treasurer :	J. H. Wainwright, M.I.Gas E., West Midlands Gas Board, Powke Lane, Blackheath, Birmingham.

North of England

Chairman :	K. E. Brown, A.M.I.Gas E., Northern Gas Board, Market Street, Newcastle-upon-Tyne.
Honorary Secretary :	W. Cummings, A.M.I.Gas E., Northern Gas Board, 30, Grainger Street, Newcastle-upon-Tyne.
Honorary Treasurer :	A. Field, M.I.Gas E., Northern Gas Board, 19 King Street, Penrith, Cumberland.

Scottish

Chairman :	D. L. Dickson, M.I.Gas E., Scottish Gas Board, Gas Offices, Cumberland Street, Dumfries.
Honorary Secretary and Treasurer :	W. Kirk, M.I.Gas E., Kessington, 29, Union Street, Greenock.

South Western

Chairman :	T. W. Jackson, M.I.Gas E., South Western Gas Board, 9a, Quiet Street, Bath.
Honorary Secretary :	F. C. Gay, M.B.E., F.C.I.S., Assoc.I.Gas E., Radiant House, G.P.O. Box No. 141, Bristol, 1.
Honorary Treasurer :	T. A. Nicholson, A.M.I.Gas E., South Western Gas Board, 34, Bridge Street, Taunton.

Wales and Monmouthshire

Chairman :	S. L. Wright, B.Sc., M.I.Gas E., Wales Gas Board, Grangetown Gas Works, Cardiff.
Honorary Secretary :	J. Powdrill, M.B.E., A.M.I.Gas E., Wales Gas Board, Bute Terrace, Cardiff.
Honorary Treasurer :	O. P. Cronshaw, M.B.E., M.I.Gas E., Wales Gas Board, 93, Wellington Road, Rhyl, N. Wales.

Affiliated Associations

Irish Gas Association

President :	W. A. Campbell, M.I.Gas E., Belfast Corporation Gas Works, Ormeau Road, Belfast.
Director :	N. J. Robertson, Assoc.I.Gas E., Alliance and Dublin Consumers' Gas Company, Dublin, Eire.

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